(2)

MISCELLANEOUS PAPER EL-89-5

PHYSICAL CHANGES IN CUTOFF BENDS ALONG THE TENNESSEE-TOMBIGBEE WATERWAY

by

F. Douglas Shields, Jr., Anthony C. Gibson

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39181-0631

1963

1969

1978

June 1989
Final Report

Prepared for US Army Engineer District, Mobile
Mobile, Alabama 36628-0001

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30 1986

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper EL-89-5	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION USAEWES Environmental Laboratory — 6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39181-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION USAED, Mobile — 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Mobile, AL 36628-0001	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO | PROJECT NO | TASK NO | WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)

Physical Changes in Cutoff Bends Along the Tennessee-Tombigbee Waterway

12 PERSONAL AUTHOR(S)

Shields, F. Douglas, Jr.; Gibson, Anthony C.

13a. TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Final report	FROM ____ TO ____	June 1989	133

16. SUPPLEMENTARY NOTATION

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	See reverse.

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Historical and future physical changes in the 38 cutoff meander bends (bendways) along the River Section of the Tennessee-Tombigbee Waterway (TTW) are examined. These areas are a major physical feature of the TTW and furnish an important biological and recreational resource. Historical changes are described by analysis and summary of results of annual hydrographic surveys of sedimentation ranges located in 14 of the bendways. Data analyzed were collected between 1977 and 1987. The volume of deposition below normal pool elevation in the 30 bendways downstream of Aberdeen Lock and Dam is estimated to be 14.4 million cubic yards (11 million cubic metres). Mean depth in the 14 monitored bendways decreased 3 ft (0.9 m), but only 3 of the 14 bendways experienced significant reductions in surface area. Deposition rates were greatest between 1981 and 1983 and slowed between 1985 and 1986 due to low discharges.

(Continued)

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code) | 22c OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

18. SUBJECT TERMS (Continued).

Aquatic habitat	Lakes	Sedimentation
Backwaters	Meanders	Tombigbee River
Channel stabilization	Oxbows	Waterways
Cutoffs		

19. ABSTRACT (Continued).

The long-term outlook for the bendways was examined by measuring the perimeter and enclosed area of tree lines depicted on repetitive aerial photographs of 26 floodplain water bodies located along seven alluvial rivers in the southeastern United States. Tree line-enclosed areas declined 1 to 9 percent per year for sites located along free-flowing rivers, with average suspended sediment concentrations of approximately 200 ppm or greater. Bendways with higher ratios of bend length to cut channel length tended to decline most slowly. Sites along canalized rivers had rates of change too low for detection with the method employed. Tree line perimeters tended to be rather stable with time relative to tree line-enclosed areas. Shorelines became more complex as lakes grew smaller. Based on these results, TTW bendways that receive little sediment from local drainage should decline in size very slowly (less than 1 percent annually) after blockage of upstream entrances to top-bank elevation. Implications of these findings for management of aquatic habitat will be treated in a subsequent report.

PREFACE

This report was prepared by the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), in fulfillment of Reimbursable Order Nos. FC87-0028 and FC88-0030. Mr. Thomas A. Lightcap of the US Army Engineer District (USAED), Mobile, was the District point of contact. Hydrographic survey data were provided by Messrs. Jim Karagan and Max Yates of the USAED, Mobile. Assistance with field inspections and dredging records were provided by Messrs. Norman Connell and Rick Saucer of the Tennessee-Tombigbee Waterway Management Center, USAED, Mobile. Suspended sediment data were provided by Mr. Fred Pinkard of the USAED, Vicksburg, and by the Mississippi and Alabama Districts of the US Geological Survey. Dr. F. Douglas Shields, Jr., and Mr. Anthony C. Gibson of the Water Resources Engineering Group (WREG), Environmental Engineering Division (EED), EL, performed data analysis, with assistance from Mses. Monette Warnock, Ella Harris, and Cheryl Lloyd. Mr. James Mock and Ms. Odessa Williams assisted with data extraction from aerial photography. Mr. Mock and Ms. Williams were employed under a summer program for high school faculty funded by the Army Research Office. Technical reviews by Dr. John J. Ingram and Ms. Anne MacDonald of the WREG and MAJ Monte Pearson of the Geotechnical Laboratory, WES, are gratefully acknowledged. The report was edited by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

The report was prepared by Dr. Shields and Mr. Gibson. The work was accomplished under the direct supervision of Drs. Shields and Paul R. Schroeder, former Acting Chiefs, WREG, and Dr. Ingram, Chief, WREG, and under the general supervision of Dr. Raymond L. Montgomery, Chief, EED, and Dr. John Harrison, Chief, EL.

Commander and Director of WES was COL Dwayne G. Lee, EN. Technical Director was Dr. Robert W. Whalin.

This report should be cited as follows:

Shields, F. Douglas, Jr., and Gibson, Anthony C. 1989. "Physical Changes in Cutoff Bends Along the Tennessee-Tombigbee Waterway," Miscellaneous Paper EL-89-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CONVERSION FACTORS, NON-SI to SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres

PHYSICAL CHANGES IN CUTOFF BENDS ALONG THE TENNESSEE-TOMBIGBEE WATERWAY

PART I: INTRODUCTION

Background

Fate of cutoff bends

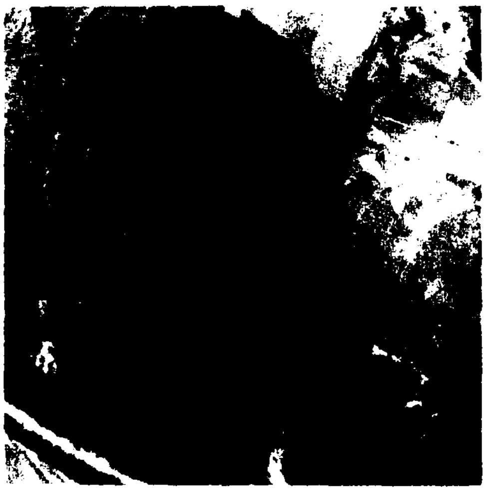
1. Gagliano and Howard (1984) developed a conceptual model of the life cycle of naturally occurring neck cutoffs along the Lower Mississippi River. Four life cycle phases were identified: the active meander-bend phase, the neck-cutoff phase, the lacustrine phase, and the terrestrial phase. The active meander-bend phase represents precutoff conditions, while the neck-cutoff phase occurs between cutoff and the time when a bar of bed material emerges at low water in the upstream bend entrance. The lacustrine stage lasts from the end of the neck-cutoff stage until the oxbow lake is filled with sediment, with a swampy meander scar being the only remnant of the original bend. Each of the four phases is illustrated in Figure 1.

2. Shields (1987) referred to the second and third stages as the blockage and infilling phases, respectively, and redefined the infilling phase as the period of time between cutoff completion and the time when the upstream end of the bendway* is blocked to top bank elevation. The infilling phase follows the blockage phase and lasts until there is no more open area within the tree line around the lake. The duration of the blockage phase is usually very short relative to the infilling phase. Bendway sedimentation during the blockage phase is dominated by deposition of bed material from the main channel in the upper limb of the bendway, particularly during higher flows. Bendway sedimentation during the infilling phase is a more gradual process of deposition of finer sediments from the main channel during overbank flows and deposition of tributary loads. If most of the bendway is filled during the blockage phase, as was the case for Kateland Bend on the Red River (Shields

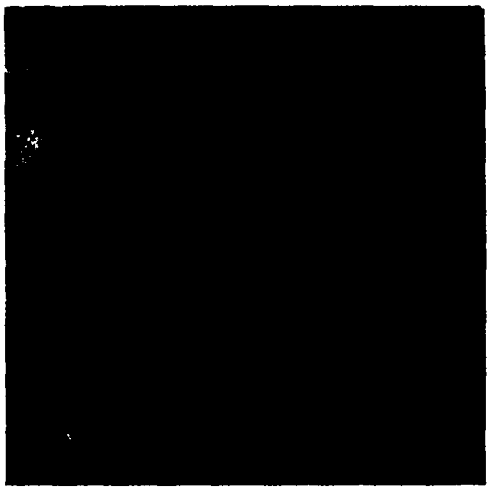
* The term "bendway" as used in this report refers to a section of old river channel that is severed by construction of a channel excavated through land that lies above the normal elevation of the navigation pool such that an island is created between the excavated channel and the old river channel (US Army Engineer District, Mobile 1984).

a. Active meander-bend phase

b. Neck-cutoff (blockage) phase



c. Lacustrine (infilling) phase



d. Terrestrial phase

Figure 1. Life cycle of cutoff meander bend as conceptualized by Gagliano and Howard (1984)

1987), or if a tributary to the bendway contributes an extremely heavy sediment load, the infilling phase is shortened.

Bendway management

3. Cutoff bends in all four stages are common along major alluvial rivers. However, along rivers stabilized or canalized for commercial navigation, no new cutoffs are allowed to occur. Therefore, as existing cutoffs proceed through the blockage and infilling phases and become terrestrial, the overall habitat diversity of the riverine system decreases. Low-velocity habitat contiguous with the main channel tends to be in short supply along canalized and channelized streams. Cutoff bends in the infilling phase, especially those that have a connecting channel with the main channel, are valuable recreational and ecological resources. These resources, however, are subject to degradation due to sediment deposition, declining water quality, aquatic plant infestation, and other factors. Personnel charged with managing the resources must find strategies for counteracting such factors and maintaining cutoff bends as quality aquatic habitats in the infilling or blockage phases.

Tennessee-Tombigbee Waterway

4. Construction of the River Section of the Tennessee-Tombigbee Waterway (TTW) involved dredging cutoff channels across 38 meander necks along the Tombigbee River, thereby creating 38* bendways (Figure 2). Throughout the development of the TTW project, the Corps of Engineers made commitments to the public and to other agencies that appropriate measures would be taken to maintain the resources of the bendways. These commitments are summarized by the US Army Engineer District (USAED), Mobile (1981), and by Shields (1987). To keep these commitments and to address concerns regarding management of the bendways, the Mobile District formed a multidisciplinary task force and conducted a bendway management study (USAED, Mobile 1984). This study resulted in a plan containing specific management recommendations for each of the 30 bendways downstream of Aberdeen Lock and Dam. The bendways located in Aberdeen Lake were not included in the management plan because they were incomplete at the time of the study. Table 1 presents a listing of the TTW

* Very low islands in Aberdeen Lake resulted in formation of three small bendways that were overlooked when the initial study (USAED, Mobile 1984) was performed. The USAED, Mobile, 1984 study identified only 35 bendways.

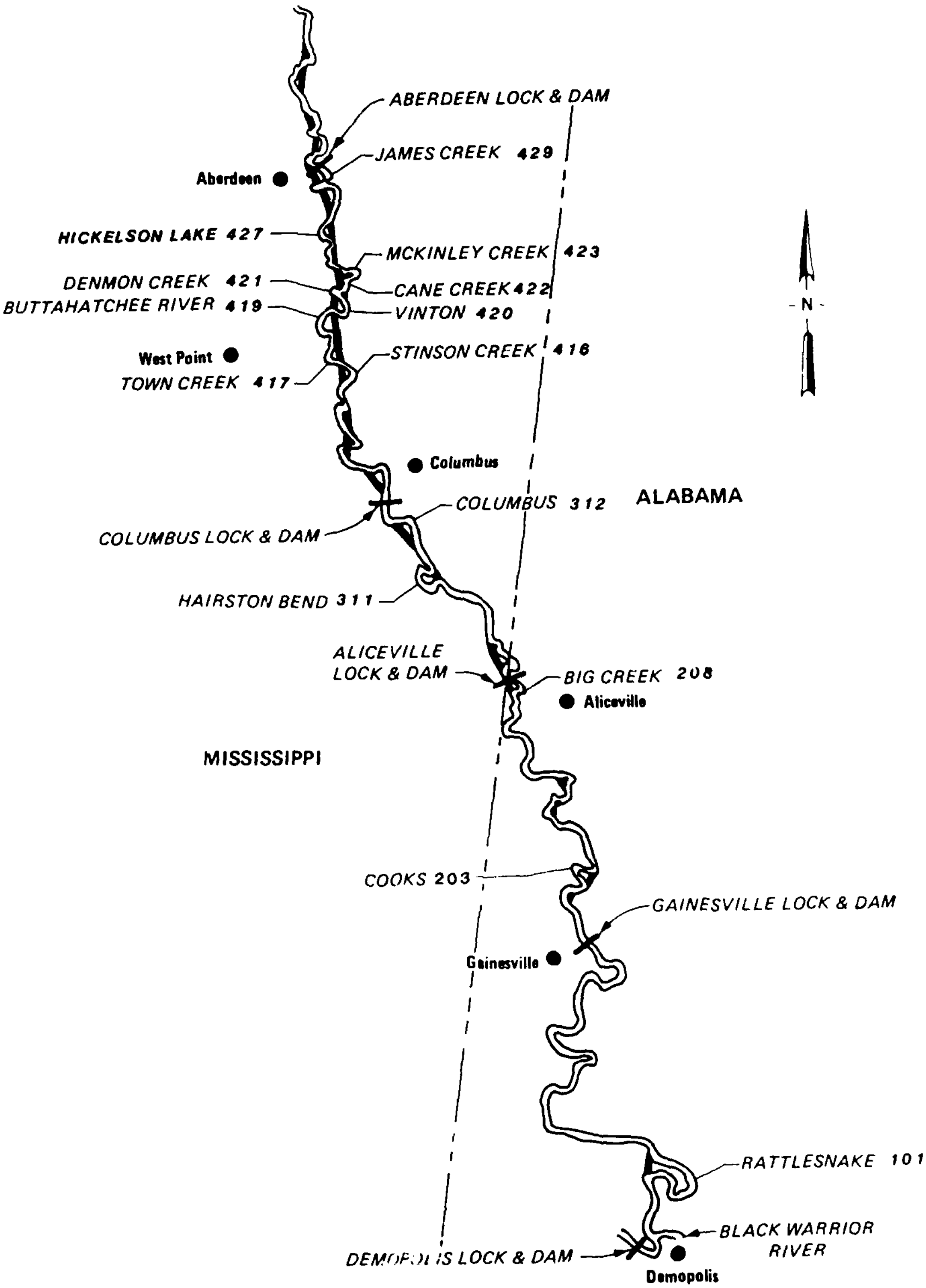


Figure 2. River Section, Tennessee-Tombigbee Waterway (numbered bendways are surveyed)

Table 1

Cutoff Bendways, River Section, Tennessee-Tombigbee Waterway

Demopolis Lake	Length ft*	Cutoff Date	Current Management Option**
Rattlesnake	51,740	1976	1
Gainesville Lake			
Warsaw	4,750	1980	1
Cooks Bend	19,540	1980	1
Windham Landing	3,700	1979	1
Cochrane	7,390	1979	1
Lubbub Creek	21,650	1979	1
Owl Creek	4,220	1979	2
Big Creek	15,310	1979	2,3
Aliceville Lake			
Pickensville	16,370	1981	1
Coalfire Creek	7,920	1981	1
Hairston Bend	29,360	1981	4
Columbus Bend	18,480	1984	1
Columbus Lake			
Waverly Ferry	4,220	1982	1
Waverly	7,390	1982	1
Waverly Mansion	3,170	1982	1
Stinson Creek	10,350	1982	1
Town Creek	10,560	1982	1
Barton Ferry	5,280	1982	1
Buttahatchee River	14,573	1982	1
Vinton Creek	8,180	1982	2
Denmon Creek	5,068	1982	2
Cane Creek	5,810	1982	2
McKinley Creek	16,160	1982	3
Richardson Lake	3,170	1982	2
New Hamilton	4,220	1982	2
Lockridge Creek	4,750	1982	2
Hickelson Lake	9,720	1982	5
Dead River	5,280	1982	2
James Creek	19,330	1982	2
Morgan Landing	4,220	1982	2,5
Aberdeen Lake			
Un-named	4,224	1984	1
Un-named	5,808	1984	1
Acker Lake	11,090	1984	1
Un-named	3,170	1984	1
Drummond Branch	9,500	1984	1
Weaver Creek	2,640	1984	1
Becker Bottoms	1,580	1984	1
Roundhouse Branch	3,170	1984	1

* To convert feet to metres, multiply by 0.3048.

** 1 = no action; bendway is either nearly filled by sediment or exhibits no significant deposition above normal water surface elevation. 2 = Top of bank blockage structure made of dredged or excavated sediment placed in upstream bendway entrance. 3 = Upstream portion of bendway was dredged. 4 = Top of bank blockage structure with small boat channel. 5 = Bendway nearly full of sediment.

bendways showing their lengths, the reservoirs in which they are located, the dates of cut completion, and the management options currently being pursued. Two of the bendways are nearly full of sediment. Eleven have been blocked, and one is partially blocked by construction of embankments at the upstream entrance.

5. Although specific measures were recommended for each bendway, the USAED, Mobile (1984), recommended that the overall bendway management policy be evolutionary in nature due to the dynamic set of circumstances operating in the bendways. It was recommended that a review study be performed 3 years after implementation of the management measures to assess the accuracy of the initial study effort and the effectiveness of the management measures implemented. This report is part of that review effort.

6. In addition to management actions, the 1984 study also recommended implementation of a program to monitor fish populations, water quality, and sediment deposition in selected bendways (USAED, Mobile 1984). Accordingly, sedimentation ranges were established in 14 of the bendways at the same time the reservoir sedimentation ranges were established, and have been surveyed at roughly annual intervals ever since. Using results of the annual bendway hydrographic surveys and similar data from other rivers, Shields (1987) devised an empirical method for predicting future rates and spatial patterns of sediment deposition in the bendways during the remainder of the blockage phase. Rates of blockage of the upstream entrances were also predicted.

7. The TTW bendways are evolving from the blockage phase to the infilling phase as sediment deposits build in their upstream segments. When upstream bendway entrances are blocked, either by man or by natural deposition, the rates of sedimentation in the bendways decrease. Shields (1987) showed that constructed blocks are advantageous because the steeper side slopes on constructed blocks allow more aquatic area to be retained in the infilling phase. Blockage of almost all of the bendways was recommended by Shields (1987). These recommendations have been partially implemented (Table 1). However, the long-term prognosis of the bendways after blockage is not well defined. Although rates of deposition are expected to radically decrease after blockage, the approximate magnitude of infilling rates and the factors controlling relative rates of filling are unknown. Also, relationships between physical and biological characteristics of the bendways have not been investigated.

Purpose

8. This report is the second in a series of three that provide technical assistance to the USAED, Mobile, in regard to its assigned mission to manage the environmental resources associated with the TTW bendways. The first report (Shields 1987) documented geometric changes that occurred in the bendways between construction of cutoffs and the 1985 survey, developed a technique for predicting future change, and recommended blockage of the bendways. The purpose of this report is to describe the geometric changes that have occurred through the 1987 survey and to provide insight into the types and rates of physical change likely to occur in the future. This investigation was designed to determine if floodplain lakes such as blocked bendways along waterways like the TTW fill with sediment rapidly enough to cause changes in lake area and perimeter that are detectable over periods as short as 30 years.

9. This report will be followed by a third study that will identify any relationships that may exist between the physical characteristics of the bendways and their biological and chemical characteristics as reported by the US Fish and Wildlife Service (1987, 1988). Similar data from bendways along other large rivers will also be examined for purposes of comparison.

Scope

10. Using methods previously described by Shields (1987), cross-sectional areas, channel volumes, and volumes of deposition were calculated from the hydrographic survey data results for each of the 14 surveyed bendways. Results of calculations are provided below in both numerical and graphical form to allow the reader to assess the changes that have occurred in the bendways since construction and since the 1985 survey. The predictive relationships proposed by Shields (1987) were verified using the post-1985 data, and predictions of rates of deposition in Aberdeen Lake bendways are provided.

11. The second objective of this report, gaining insight into the long-term prognosis for the bendways, focuses on the future of bendways that are blocked by man or natural deposition. Sequential aerial photographs of natural and man-made bendways along the Tombigbee, Arkansas, Verdigris, Mississippi, Red, Black Warrior, and Ouachita Rivers were used to determine

the kinds and rates of change of lake surface area and perimeter that occurred over several decades. Reasons for differential change are proposed and investigated. Application of these findings to TTW bendways concludes the report.

PART II: APPROACH FOR STUDY OF INFILLING PHASE

Mathematical Modeling

12. Even after the TTW bendways are blocked at the upstream entrance and enter the infilling phase, they remain attached to the adjacent navigation lake or pool at the downstream end and their water levels rise and fall with the pool operation. During floods, many of the bendways are hard to distinguish from other parts of the reservoir. Sediment deposition in the bendways during at least the early stages of the infilling phase is therefore a special class of reservoir sedimentation.

13. Mathematical reservoir sedimentation models are available that allow prediction of the depth of deposited sediment as a function of longitudinal distance along a reservoir center line when a equilibrium state is established. Less accurate, but similar techniques are also available that allow prediction of deposition as a function of time and distance for the period prior to establishment of equilibrium (Annandale 1987). These types of techniques are inappropriate for simulating sedimentation in the blocked bendways because the morphology of the bendways is so different from a typical wedge-shaped reservoir, particularly in the directions lateral and longitudinal to the channel. Furthermore, TTW bendway water surface elevation is controlled by the water surface elevation in the main channel at the downstream entrance rather than by a dam at the downstream end. Finally, bendways are subject to inputs of sediment from the main channel during overbank floods, and typical reservoir sedimentation models do not account for this or similar phenomena. Even if reservoir sedimentation models could be adapted for simulating deposition in the TTW bendways, existing data are inadequate for such an application, and collection of an adequate data set for a representative number of bendways would be very costly. For these reasons, deterministic mathematical simulation models were not used herein to predict the long-term prognosis for the bendways. Instead, the likely rates of future change in the blocked bendways were studied by examining historical sequential aerial photographs of cutoff bendways and oxbow lakes located along the Tombigbee and similar rivers.

14. Aerial photography was chosen as the primary data source, because suitable survey data are not available for a sufficient number of sites

representative of a range of conditions. Aerial photographs of sites along several major southeastern US rivers are available for periods of record up to 50 years. On the other hand, determinations of bendway geometry from aerial photographs is decidedly inferior to direct measurement using hydrographic surveys. Shortcomings of the data from aerial photographs are discussed in Part III, Data Collection and Analysis.

Conceptual Model

15. A conceptual model was used to identify the major variables that control the rate of bendway sedimentation during the infilling phase. Using the resultant list of controlling variables or factors, a set of site selection criteria was then developed. The mass of sediment deposited in a bendway during a given period of time is given by

$$\text{Mass deposited} = \text{Mass in from local drainage area} + \text{Mass in from main channel} - \text{Mass out}$$

The mass deposited at a given time t after cutoff is given by multiplying the volume times the mean density of sediment deposits between cutoff and time t.

16. Thus, bendway sedimentation during the infilling phase is the superposition of two independent (more or less) processes: deposition of sediment transported by the master stream during overbank floods and deposition of sediment contributed to the bendway from its local drainage area.

a. The first process results in a fairly uniform distribution of sediment along the bendway, while the second process results in more localized delta-like deposits. All of the TTW bendways are subject to the first process. The rapidity of this process depends on the frequency and duration of overbank flows, the concentration of suspended sediments in overbank flows, sediment characteristics such as fall velocity, and local conditions such as valley width, valley slope, and the presence of ridges or other types of flow obstructions.

b. The second process is controlled by the size and quantity of sediment flowing into the bend from the local drainage area and the trapping efficiency of the bend. In most cases, since bend channel cross sections are large relative to the contributing tributaries, it is reasonable to assume that the bendways are

extremely efficient at retaining even fine sediments. The final state of a bendway that receives inflow from a perennial tributary should be a channel that follows the thalweg of the old river channel but has a cross section similar to the tributary.

17. Bendways in the infilling phase may be categorized as either those that receive significant inputs of sediment from both tributaries as well as the main channel or as those that receive little sediment from sources other than the main channel. The ratio of mean annual runoff to bendway volume and the average sediment concentration in this inflow is of importance for the former category. Bendways protected from overbank flooding from the main channels by flood control levees between the bendway and the master stream represent another category, but none of the TTW bendways meets that description. Therefore, this type of bendway will not be considered further herein.

18. Six of the 11 TTW bendways that are currently blocked receive inflows from perennial tributaries. However, ephemeral channels and ditches can be major contributors of sediment as well as perennial streams. Sediment loads from ephemeral channels draining disturbed watersheds have filled Hickelson Lake bendway and partially filled Dead River bendway. The remaining five blocked bendways evidently do not have major sediment sources in their drainage basins.

19. Additional important controlling factors include the type and quantity of sediment transported by the master stream, master stream hydrology during the period of interest, influence of dams on the master stream, and initial geometry of the bendway. Factors that influence flow phenomena in the vicinity of the bendway during high flows are also of interest; among these are valley width, valley slope, local obstructions to flow, and the proximity of tributary confluences with the master stream to the bendway.

Approach

20. Twenty-six sites--either natural oxbows or cutoff bendways--that provided a range of physical conditions bracketing those found on the TTW were selected for study. Measurements of area and perimeter were extracted from sequential aerial photos of the selected sites along with qualitative observations. The rates of change of bendway and natural oxbow lake area and perimeter were calculated in units of percent per year. The relationships of

differential rates of change to the previously identified controlling factors were also explored. Methods used for analysis are described in the next part of this report.

PART III: DATA COLLECTION AND ANALYSIS

Blockage Phase Analysis

21. The blockage phase analysis involved the determination of historical changes in some of the TTW bendways. To monitor physical changes, permanent sedimentation ranges were established on the five largest bendways downstream of Columbus Lock and Dam (Rattlesnake, Cooks, Big Creek, Hairston, and Columbus) and on 9 of the 18 bendways in Columbus Lake. The number of sedimentation ranges per bendway ranged from a low of three for Cane Creek, Denmon Creek, and Vinton Creek bendways to a high of 15 for Rattlesnake Bend. Distances between ranges varied from a few hundred feet to a little more than a mile, with ranges tending to be closer in the upstream portions of the bendways. Surveys of these ranges were collected at roughly annual intervals after the navigation pools were raised and after 1977 for Rattlesnake Bend. The periods of record are summarized in Table 2. More detail regarding the hydrographic survey data base is provided in Appendix A.

Table 2

Periods of Record, TTW Bendway Hydrographic Surveys

Pool	Pool Raised	No. of Bendways	Cutoff Construction	Period of Record Hydrographic Surveys
Demopolis	--	1	1976	1977-87
Gainesville	1978-79	7	1979-80	1977-87
Aliceville	1979	4	1981-84	1981-87
Columbus	1981	18	1982	1981-87
Aberdeen	1984	8	1984	1984-87

22. Range surveys were conducted by contractors using boat-mounted acoustic fathometers for subaqueous portions of the cross sections and conventional transit-and-rod surveying instruments for extremely shallow areas and overbanks. Ranges were marked using permanent markers or monuments. Contractors provided cross-section survey data to the Mobile District in digital form.

23. The TTW hydrographic survey data were checked and reduced using the procedures described by Shields (1987). Large-scale computer-generated plots of each cross section were visually inspected. Plots of several surveys of the same range were drawn on the same sheet for ease of comparison. In a few cases, the magnitude and direction of bed or bank changes were inconsistent with both prior and subsequent surveys, and with other surveys in the same bend or cut. In cases where these changes could not be explained, the data in question were removed from the data base. The checked data were used as input to a FORTRAN computer program named Bendway Sedimentation Data (BSD), which computes channel cross-sectional area, mean depth, and channel width at each range and volume of each bendway and cut channel. Details regarding program use were provided by Shields (1987).

24. Data output from BSD were used to compile tabulations of bendway channel cross-sectional area, channel volume, and volumes of deposition, both below top-bank elevation and below normal pool elevation. Cross-sectional area was plotted as a function of river mile for each bendway for the earliest and most recent surveys. Deposition volumes for each bendway were plotted against time. In addition, the cross-sectional surveys for ranges closest to the upstream entrance of each bendway were plotted. Plots were then placed side by side and compared.

25. Output from BSD was also entered into microcomputer spreadsheets and used to calculate mean depth and surface area at normal pool elevation for each bend for selected years. Rates of change of area and depth were computed.

26. Shields (1987) used TTW bendway hydrographic survey data obtained from cutoff construction through 1985 to calculate dimensionless coefficients that measure the rates of deposition in the bendways and the rates of scour of the cut channels. As part of the study described herein, the bendway volume decay coefficients and cut channel growth coefficients were recomputed using results of the 1986 hydrographic surveys and discharge records. The new coefficients were compared with the original ones to determine if the predictions of the earlier study are still valid. Similar calculations were not performed using the 1987 data because several of the bends were blocked or dredged prior to the 1987 survey, and because discharge records were not available for this study.

Infilling Phase Site Selection

27. Eleven rivers, or major waterway reaches, were initially identified as locations for potential study sites. Of these, seven were adopted as study reaches: the Tombigbee, Arkansas, Verdigris, Red, Ouachita, Mississippi, and Black Warrior Rivers (Figure 3). Natural cutoffs were of interest along the Tombigbee, Black Warrior, and Ouachita Rivers, while man-made cutoffs were potential study sites along the Mississippi and Red Rivers. Both types of cutoffs were of interest along the Arkansas-Verdigris system. Potential study sites were initially located by studying navigation charts and US Geological Survey (USGS) quad sheets covering the study reaches. Data from 25 to 30 sites were needed to have enough data to examine the most basic relationships between the controlling variables and the rates of change of bendway area and perimeter (Stevens and Barcikowski 1980). The following criteria were used to select candidate sites from the maps:

- a. Sites must be natural or man-made bendways in the infilling phase for more than 15 years. Appropriate aerial photo coverage must be available. Additional detail regarding selection of aerial photos is given below.
- b. Sites must be subject to overbank flooding from the master stream. If flood control levees are present, the bendway must be on the river side of the levees.
- c. Sites should be located along medium to large alluvial, perennial rivers draining humid or subhumid watersheds. The overall hydrology of the reach should be similar to the Tombigbee River.
- d. Sites should not have been dredged or used as dredged material disposal areas during the period of interest.
- e. Sites must provide a wide range of values for master stream sediment load, bendway drainage area, bendway age, and bendway surface area. In addition, some of the sites should be along rivers impounded by run-of-river reservoirs, and a range of reservoir ages should also be represented.

Thirty-two candidate bendways in the infilling phase were selected as candidate sites, but data from only 26 were used in analyses. Photo coverage of 6 of the 32 sites had either inadequate quality or temporal distribution, while one of the sites was in the terrestrial phase for the entire period of record. Seven of the 26 sites that were used were previously examined (Shields 1987). Characteristics of each site are summarized in Table 3.

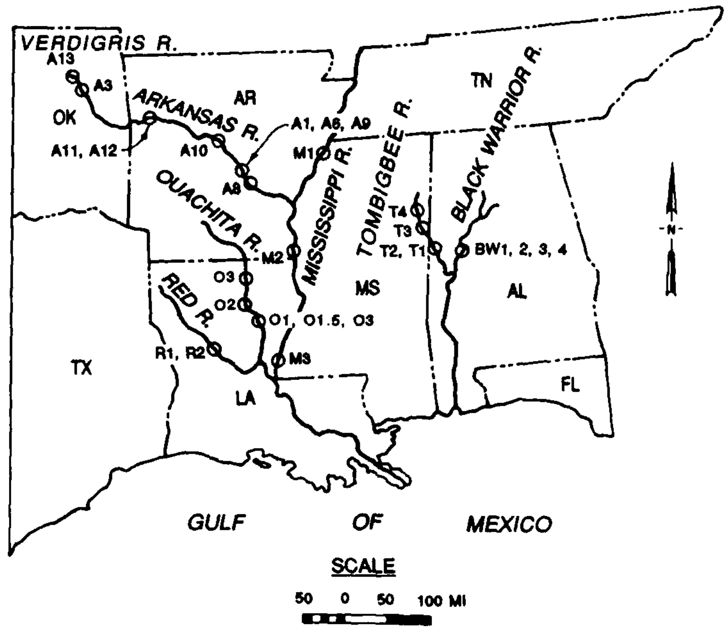


Figure 3. Infilling phase study sites

Infilling Phase Data

Selection and acquisition of photography

28. A tabulation of available aerial photography for each of the selected sites was obtained by marking the regions of interest on photocopies of maps and sending the maps to agencies holding photo collections. A tabulation of photos of the Arkansas River sites was obtained from the USAED, Little Rock, while coverage of all other sites was ordered from the National Cartographic Information Center of the USGS or the Aerial Photography Field Office of the US Agricultural Stabilization and Conservation Service (ASCS). Similar information was requested from the US National Archives and Records Administration for sites that were in the infilling phase prior to 1940. Coverage of Tombigbee River sites was also ordered from the USAED, Mobile.

29. Tabulations of available aerial photos were examined, and photos were selected for acquisition. Photography was selected with the goal of providing at least four coverages of each site at fairly regular intervals during the infilling phase. In general, more photos were ordered for each site than were needed to allow for inadequate photo quality and uncertainty regarding

Table 3

Basic Characteristics of Infilling Phase Study Sites

River	Site No.	Site Name	Man-Made or Natural	USGS Quad Sheet	Bendway Age, years	Currently in or along Reservoir Pool	Small Dam*
Tombigbee	T2	Lubbub Creek	N	Aliceville S., AL	>50	Yes	No
	T3	Lake Catherine	N	Columbus, MS-AL	50<A<165	Yes	Yes
	T4	None	N	Amory SW, MS	>50	Yes	Yes
Arkansas	A1	Old River Lake	N	Wright, AR	>50	Yes	No
	A6	Case Bar	M	Woodson and Keo, AR	26	Yes	No
	A8	Hensley Bar	M	White Hall, AR	36	Yes	No
	A9	Brodie	M	Wright, AR	31	Yes	No
	A10	Morrilton	M	Houston and Gleason, AR	38	Yes	No
	A11	McLean	M	Coal Hill, AR	33	Yes	No
	A12	Trustee	M	Lavaca and Alma, AR	34	Yes	No
Verdigris	A13	Catoosa	M	Catoosa, OK	>16	Yes	No
	A3	Old River Channel	N	Catoosa SE and Neodesha, OK	>37	Yes	No
Red	R1	Dixon Bend	M	Canfield and Doddridge, NE	25<A<32	No**	No
	R2	McNeeley	M	Boyce and Colfax, LA	40	No**	No
Ouachita	O1	Tew Lake	N	Jonesville N, LA	>50	Yes	Yes
	O15	Mean Lake	N	Jonesville N, LA	>50	Yes	Yes
	O2	Horseshoe Lake	N	Columbia, LA	>50	Yes	Yes
	O3	Horseshoe Lake	N	Monroe N, LA	>50	Yes	No
	O4	Rawson Creek (Dry Lake)	N	Harrisonburg, LA	>50	Yes	No
Mississippi	M1	Hardin	M		46	No	No
	M2	Worthington	M		55	No	No
	M3	Glasscock	M		55	No	No
Black Warrior	BW1	Storer Lake	N	Koxville and Moundville W, AL	>50	Yes	No
	BW2	Bohanon's Cutoff	N	Knoxville and Moundville W, AL	38<A<52	Yes	No
	BW3	King's Cutoff	N	Moundville, W, AL	>50	Yes	No
	BW4	Keaton Lake	N	Fosters and Moundville W, AL	>50	Yes	No

* Aerial photos show a small dam constructed across one end of the old bend.
** As of most recent photo date.

the dates of cutoff and blockage. Black-and-white, color, and color infrared imagery were all used. Only photography with original scale 1:40,000 or larger was selected. With the exception of photos ordered from the USAED, Mobile, 1:12,000 (nominal scale) enlargements were requested. Appendix A presents a list of the photographs used in this study.

Data collection

30. Aerial photos were logged into a data base and sorted by site as they were received. When all photos for a given site had been received, they were placed side by side for comparison, and notes were made regarding visible changes in the bendway, its drainage area, or the master stream (Figure 4). A subset of the photos obtained for each site was then selected for tracing and digitizing, based on photo quality and temporal coverage.

31. Photos selected for tracing and digitizing were secured to a table with tape, and clear tracing film was taped over each photo. In cases where more than one photo was needed to cover a site, a mosaic was built by taping the first photo underneath the film overlay, locating two or more common reference points on the base and adjacent photo, marking the location of these points on the overlay, and then using the marks on the overlay to guide

Figure 4. Examination of sequential aerial photos

placement of the second photo, thus producing a semicontrolled mosaic. Each overlay was clearly labeled with the site name and number, photo date, photo number(s), and the current date.

32. Tree lines surrounding each oxbow lake were traced onto the overlay. A small hand-held magnifier was used to aid interpretation as needed. Tree lines were interpreted from the photos based on changes in tone, texture, or, in the case of color or color infrared photos, color. Trees were generally darker than water on the black-and-white photos, and much darker than sandy sediments. An effort was made to avoid the effect of short-term lake water-level fluctuations by concentrating on the tree line rather than the water's edge. Photographs taken during floods were not used. Additional care was used when interpreting photos taken at low stage to avoid interpreting the boundary of dark sediments or herbaceous vegetation as the tree line. In general, neither of these two types of features had as rough a "texture" as trees. The influence of shadows cast by trees in photos taken at low sun angles was also subjectively counteracted. The shadows are shown as a dark band while the trees are lighter. Photography for the more dynamic Arkansas River sites that was analyzed by Shields (1987) was reexamined to ensure consistent interpretation.

33. Two or more definite reference points visible on the photo and on the 1:24,000 USGS quad sheet of the area were also marked on the overlay and labeled with a letter of the alphabet. A north arrow was constructed on each tracing by measuring the angle between the north arrow on the quad sheet and the line between the two reference points (or some other easily defined line visible on both the maps and the photo).

34. Cartesian coordinates for the reference points were determined using a GeoGraphics drafting board digitizer with Measugraph software running on an IBM PC/XT microcomputer. These coordinate pairs were transferred to each tracing and were used along with the north arrow to calibrate the digitizer for each tracing. This method of calibration removed the effect of minor scale variations and some two-dimensional distortion. The outlines of the tree lines were digitized from each tracing, from which the enclosed surface area and perimeter were calculated. Surface areas of islands were subtracted from the overall enclosed surface area, and the island perimeters were added to total tree line perimeter.

35. Tracings were checked by plotting the digital tree line data on transparencies at a constant scale for each site. All transparencies for a given site were then overlaid for comparison. Normal changes in tree lines were a general shrinking or general enlargement due to sedimentation or raised water levels, respectively. Major changes in lake shape or location or changes in distances between fixed points such as training structures were due to map inaccuracy, photo distortion, mistakes in photointerpretation, or mistaken location of reference points. When such mistakes occurred, an effort was made to correct them, and transparencies were again compared. If correction was unsuccessful, the tree line area and perimeter data were removed from further analysis. Area and perimeter data were not eliminated if the transparencies showed only slight rotation or translation of the tree lines.

36. After checking, the enclosed area and perimeter data were entered into a microcomputer spreadsheet. The ratios of area and perimeter to the initial area and perimeter were calculated, as was the shoreline development index (SDI).

37. The SDI (or shoreline development ratio) of a water body is the ratio of the perimeter to the circumference of a circle of equal area (Headquarters, US Army Corps of Engineers 1987). The SDI is given by

$$SDI = \frac{P}{2\sqrt{\pi A}}$$

where

P = perimeter, ft

A = surface area, sq ft

Dates of impoundment of the master stream adjacent to the bendway and of the bendway itself if a dam was built across one end were also added to the data base.

Sources of error

38. In this study, the area enclosed by woody vegetation around man-made bendways and natural oxbow lakes was used as a surrogate for lake size. Water surface area was not used because it varies with lake elevation. Problems associated with the use of vegetation are numerous; however, they do not contribute significant error to this type of study. It is important to note that determination of shoreline location was not an objective of this study,

nor was exact measurement of tree line-enclosed area. Instead, the average rates of change in tree line perimeter and tree line-enclosed area were of interest.

39. Vegetation tends to respond gradually to changes in lake size due to sediment deposition or permanent increases in water surface elevation due to impoundment. In the former case, it takes time for trees to become established on sediment deposits, and this period may range from a few months to a few years depending on climate, flooding, and soil characteristics. In the latter case, if trees are not cleared prior to impoundment, they gradually die and decay. Therefore, observed changes in tree line-enclosed area following impoundment tended to be gradual rather than abrupt. Due to individual differences, tree lines tended to be irregular and ragged during periods of change. Low vegetation can be covered by high water; grasses and herbaceous vegetation can be misinterpreted as trees during periods of low and normal stage. Finally, the initial coverage of at least one site (R2) had no trees within a long distance of the bendway due to agricultural activities; this problem was solved by using the very obvious break in slope (interpreted from tone contrast) at the top of the bank as the "tree line."

40. Other problems identified above were addressed by careful selection and interpretation of photography. Photos depicting overbank flooding were not used. Magnifiers and occasionally a stereoscope were used to confirm differentiation between trees and lower vegetation. Interpretation was done by only two individuals working closely together to ensure consistency. Average rates of change in lake size were computed by fitting linear regression functions to the tree line-enclosed area versus time data to damp the influence of minor variations.

41. Some error was introduced by distortions in the photographs. Scale variation due to vertical relief was not significant because of the low relief of the study areas. Although the photos obtained from the ASCS were rectified to remove tilt and the USGS photography was generally of very high quality, some photos had slight distortion near their borders. In addition, most photos had scales slightly more or less than nominal. These problems were addressed by using reference points from USGS quad sheets and avoiding, whenever possible, use of areas away from the central 50 to 60 percent of the photos. Furthermore, the effectiveness of these measures was checked by overlaying transparency plots of the digitized data as described above.

42. Some error was introduced by measurement of tree lines from semicontrolled mosaics for sites that required more than one photo for complete coverage. Parallax differences and minor scale variations among photos used in a mosaic can distort the resulting photographic map. About 35 percent of the reported observations of tree line perimeter and enclosed area were from semicontrolled mosaics. Although this error was not quantified, it is believed to be acceptably small, since the resultant photographic maps were checked for consistency by overlaying transparencies of the tree lines extracted from them as described above.

43. According to Ebert and Associates (in preparation), at least 90 percent of well-defined reference points depicted on 1:24,000 USGS quad sheets are within 40 ft* of their "true" location. Thus, use of reference points from quad sheets to calibrate the tracings may have introduced error in the measurements of tree line-enclosed area and perimeter. Percentage error would be greatest for the smaller sites. The smallest area measured was about 10 acres. If this area were a rectangle 10 times longer than wide, and if the locations of the opposite corners were each 40 ft in error in perpendicular directions, the actual area would be between 8 and 12.3 acres. The maximum error in tree line area associated with use of the map reference points is therefore about 20 percent. Similar reasoning produces a potential error of about 7 percent for an area of 100 acres and 2 percent for an area of 1,000 acres.

44. Additional error may have arisen due to use of the digitizer. Results of digitizing were checked by repetition to minimize operator error. The accuracy of the digitizer (0.00125 in.) likely exceeds the accuracy of the human operator.

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 5.

PART IV: RESULTS AND DISCUSSION

Changes in TTW Bendways--Blockage Phase

Channel volume

45. Initial surveys of the 14 monitored bendways were conducted in 1977-81. All of the bendways except Rattlesnake Bend were surveyed at least once prior to cutoff. Between the initial surveys and 1987, total bendway volume below normal pool elevation has decreased by about 8.7 million cubic yards, or 18 percent. If the 1984 survey is used as the initial survey for Columbus Bend, the volume of total deposition for all 14 bendways increases to 9.5 million cubic yards, or about 20 percent of the initial volume. Table 4 summarizes changes that have occurred in the bendways since the initial surveys. Table A2, Appendix A, shows measured channel volumes for each year and bendway. The volume of deposition below normal pool elevation in each of the 14 bendways as of 1987 is depicted in Figure 5. The bendways are listed on the left side of Figure 5 in streamwise order. The first nine listed are in Columbus Lake (Figure 2). These nine bendways have experienced more deposition, percentage wise, than the other five, and in less time. No apparent relationship was found between the volume of deposition in a given bendway in Columbus Lake and its longitudinal position in the reservoir (Figure 6).

46. Of the 14 monitored bendways, only Columbus Bend had a 1987 channel volume greater than the initial survey volume. The channel of this bend was scoured by high flows subsequent to the initial (1981) survey but prior to cutoff completion (1984). The bars for Columbus Bend in Figure 5 are based on changes between 1984 and 1987. The surveys for 1984-87 show that the bend has filled rapidly since cutoff completion. The 1987 volume below normal pool elevation was only 84 percent of the volume at the time of cutoff in 1984. Furthermore, the 1987 volume is probably greater than it might otherwise be because of dredging in the bendway associated with recent commercial developments.

47. The changes in bendway volume, deposition volumes, surface area, and mean depth discussed herein are based only on differences between the initial survey and the 1987 survey. A certain amount of material has been dredged from some of the bendways, while at least one of the bendways has received material dredged from the navigation channel. Table 5 is a partial

Table 4

Changes Below Normal Pool Elevation in the 14 Monitored TTW Bendways as of 1987

Bendway	1987 Remaining Volume, Percent of Initial	Deposition million cu yd	1987 Mean Depth ft	Change in Mean Depth ft	Estimated 1987 Surface Area acres	Change in Surface Area acres
Rattlesnake Bend	83	3.470	23.5	-3.9	449.5	-14.5
Cooks Bend	82	1.600	16.6	-4.8	276.2	+15.6
Big Creek	52	0.522	4.4	-2.6	80.5	-16.4
Hairston Bend	87	0.799	9.0	-1.4	361.5	+1.1
Columbus Bend*	115,84	-0.306,0.440	11.9	0.5,-2.1	120.2	+11.3,+11.4
Stinson Creek	81	0.417	11.7	-2.1	95.0	-4.3
Town Creek	91	0.167	14.4	-0.4	69.7	-5.1
Buttahatchee River	79	0.421	11.0	-3.0	87.0	0.0
Vinton Creek	68	0.272	10.5	-5.1	34.7	+1.0
Denmon Creek	79	0.090	10.9	-3.7	19.9	+1.3
Cane Creek	60	0.182	7.8	-4.0	21.3	-2.3
McKinley Creek	68	0.403	5.0	-4.3	105.6	+21.9
Hickelson Lake	4	0.415	0.6	-8.2	18.4	-12.1
James Creek	64	0.303	4.8	-3.4	68.9	+10.6
All 14 bendways	81	9.503	13.8	-3.0	1,808.4	+8.2
Maximum	115	3.470	23.5	-8.2	449.5	+21.9
Minimum	4	0.155	0.6	-0.4	18.4	-16.4
Columbus Pool bendways (9)*	74	2.670	9.0	-3.4	520.5	+11.1

* Note: Two numbers are given in each column for Columbus Bend. The first number is based on using the 1981 survey as the initial survey, while the second is based on using the 1984 survey as the initial. Summary figures in the lower part of the table are based on using the 1984 survey as the initial survey for Columbus Bend.

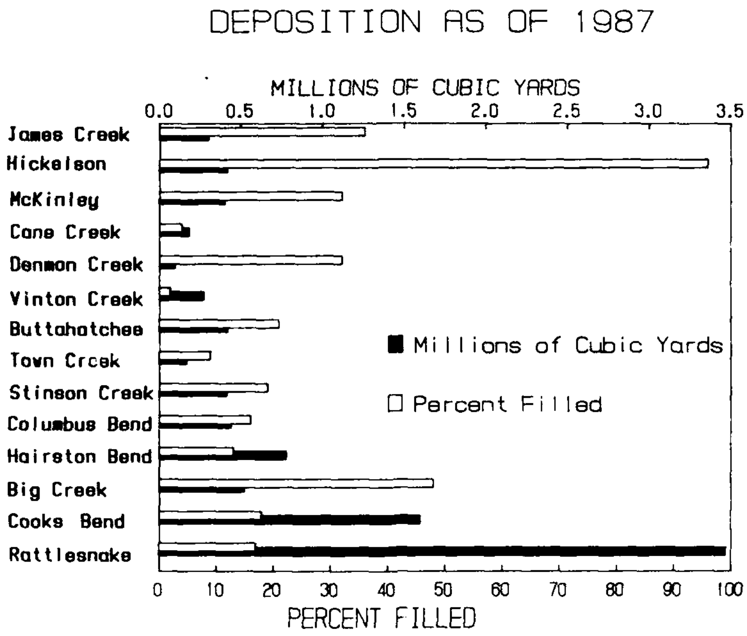


Figure 5. Deposition in the 14 monitored TTW bendways as of 1987

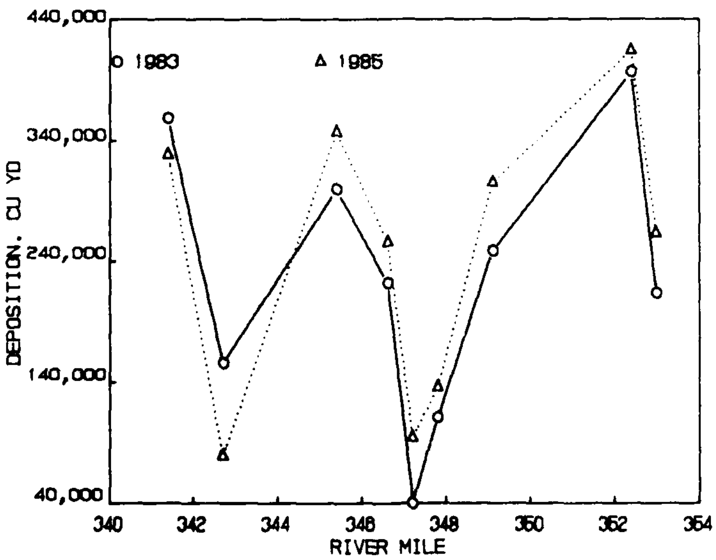


Figure 6. Deposition in Columbus Lake bendways versus navigation mile at upstream bendway entrance

listing of quantities dredged from or placed in TTW bendways. Table 5 was abstracted from data provided by the Tennessee-Tombigbee Waterway Management Center. Data provided by the TTW Management Center are reproduced in Table A3, Appendix A.

Table 5

Dredging and Disposal in TTW Bendways

Year	Bendway	Dredged Volume cu yd	Description
1981	Big Creek	145,000	Dredged out of bendway
1987	Hairston Bend	30,527	Dredged out of bendway
1987	McKinley Creek	87,381	Dredged out of bendway
1987	Owl Creek	-18,582	Disposed into bendway
	Total (net)	244,326	

Mean depth

48. The BSD computer program computed mean depths for each cross section by dividing the cross-sectional area by the channel width at normal pool elevation. These mean depths were then weighted with the distance between ranges and averaged to obtain the overall mean depths for each bend which are shown in Table 4. Mean depth for all 14 bendways has decreased from 16.8 ft to 13.8 ft, or about 18 percent. The largest changes in mean depth occurred in Hickelson Lake, Vinton Creek, and Cooks Bend bendways. The 1987 mean depths calculated for Vinton, Denmon, and Cane Creek bendways are based primarily on the survey ranges located in the middle and lower portions of those bendways because the survey ranges in the upstream entrance were coincident with the blockage structures.

Surface area

49. Rough estimates of initial and final surface area for each bend were computed by dividing the volume below normal pool elevation by the mean depth. Changes in total surface area have been negligible, and evidently most of the observed 20-percent change in bendway channel volume has occurred due to deposition below the normal water surface elevation.

Rates of change

50. Total deposition below normal pool elevation is plotted as a function of time in Figure 7. Total deposition shown in Figure 5 is calculated using the 1981 survey as the initial survey for Columbus Bend. The rate of total deposition was greatest between 1981 and 1983. Factors that influence the shape of the total deposition curve in Figure 5 include the following: (a) the deposition totals for the earlier years (1978-80) include only the bendways that were cut off prior to that time (Rattlesnake, Big Creek, and Cooks Bend), (b) as the upstream entrances of the bendways become blocked with sediment, less sediment is transported into them from the main channel, and (c) the 1985 volume for Rattlesnake Bend (see Table A2, Appendix A) was rather high, leading to a low figure for deposition for that year. The 1985 values for Rattlesnake are probably the result of survey inaccuracy.

51. Table 6 summarizes the rates of change of bendway channel depth and volume. The rate of change of mean depth below normal pool elevation (also the vertical accretion rate) for all bendways has been about -0.6 ft/year. The most rapid vertical accretion has been observed in Hickelson Lake, Cane Creek, Denmon Creek, and Vinton Creek bendways. Hickelson Lake bendway has been filled by sediments from a nearby surface mine; the rates for the other three are influenced by the fact that the calculated 1987 bend channel volumes may be somewhat low since blockage structures were constructed in the vicinity of survey ranges.

52. Table 6 also shows annual deposition rates in units of cubic yards per mile of bendway channel and cubic yards per acre of bendway surface area at normal pool elevation. The coefficients of variation (the standard deviation divided by the mean) of these two parameters show that they vary little from bend to bend. They may be used for rough postdiction of the volume of sediment deposited to date in the unmonitored bendways. They are not useful for prediction of future deposition, however, as the rate of deposition is a log-decay function of cumulative discharge in the main channel, and not a simple linear function of time (Shields 1987). Application of the annual deposition rate in cubic yards per mile to the length and age of the unmonitored cutoffs yields the volumes of deposition below normal pool elevation shown in Table 7.

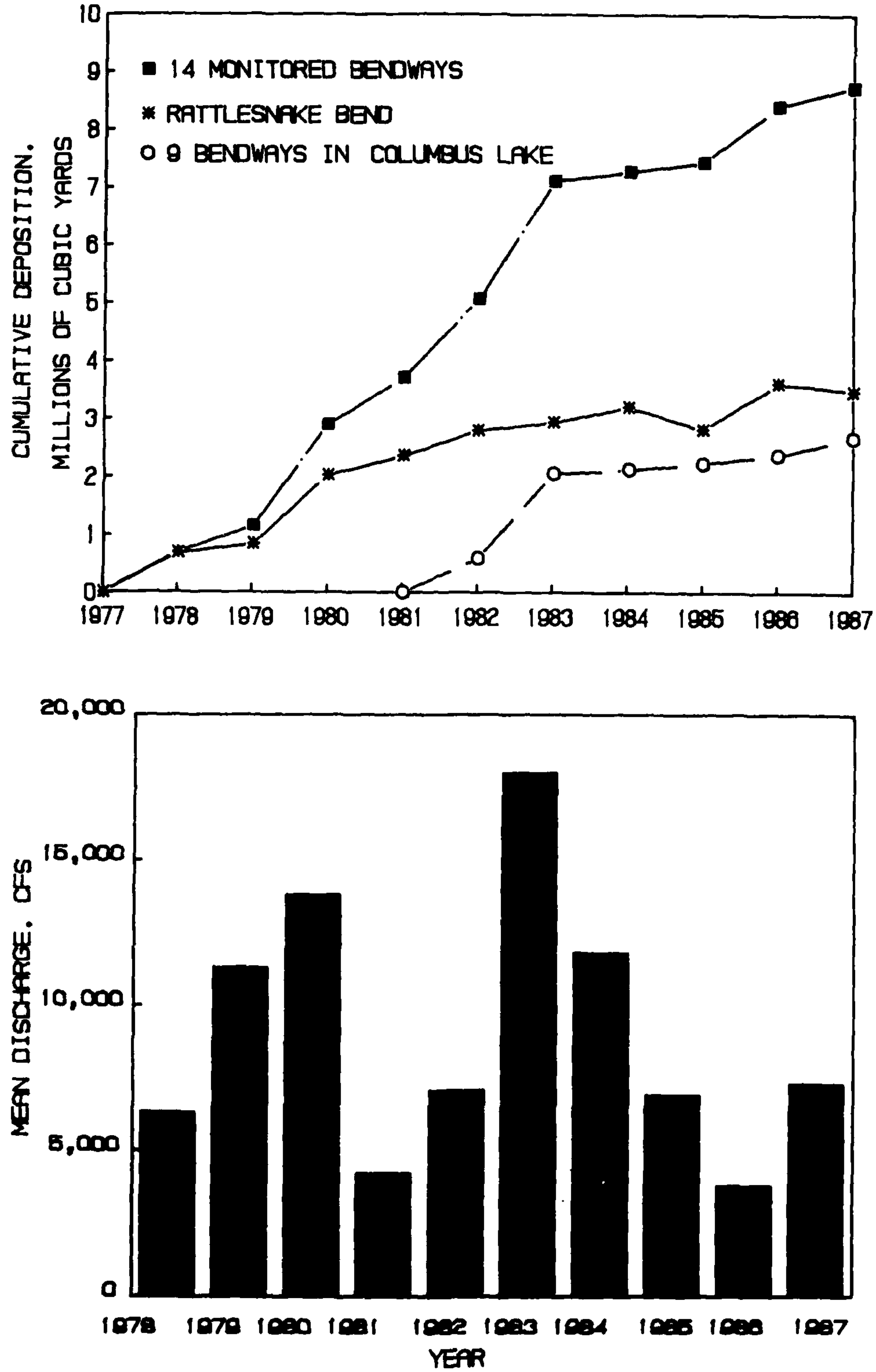


Figure 7. Deposition below normal pool elevation for TTW bendways and mean discharge for Tombigbee River at Aliceville Lock and Dam

Table 6

Rates of Change, 14 Monitored TTW Bendways

Bendway	Years of Record	Change in Mean Depth ft/yr	Annual Deposition	
			Cubic Yards/Mile of Bendway	Cubic Yards/Acre of Bendway Surface Area*
Rattlesnake Bend	10	-0.4	35,415	748
Cooks Bend	9	-0.5	48,038	682
Big Creek	10	-0.3	18,016	539
Hairston Bend	6	-0.2	23,945	369
Columbus	3	-0.7	41,905	1,347
Stinson Creek	6	-0.4	35,446	700
Town Creek	6	-0.1	13,917	372
Buttahatchee River	6	-0.5	25,447	807
Vinton Creek	6	-0.8	29,248	1,344
Denmon Creek	6	-0.6	15,699	811
Cane Creek	6	-0.7	27,595	1,288
McKinley Creek	6	-0.7	21,970	804
Hickelson Lake	6	-1.4	37,564	2,269
James Creek	6	-0.6	13,799	867
Maximum	10	-1.4	48,038	2,269
Minimum	3	-0.1	13,799	369
Mean	6.6	-0.6	27,710	925
Standard deviation	1.8	0.1	11,485	145
Coefficient of variation	0.3	0.2	0.4	0.2
Columbus Lake bendways (9)	6	-0.6	25,200	873

* At normal pool elevation.

Table 7

Estimated Volume of Deposition Below Normal Pool Elevation in Bendways

Lake	Average Deposition cu yd/mile per year	Estimated Total Deposition in 1987 million cu yd
Columbus	25,200	3.88
Aliceville	32,500	2.10
Gainesville	33,000	4.91
Rattlesnake Bend	34,700	3.47
Total (30 bendways)		14.40

53. Shields (1987) presented a procedure for predicting the rate of deposition in cutoff bendways during the blockage phase and applied it to the TTW bendways located below Aberdeen Lock and Dam. To check the validity of these predictions, the dimensionless volume decay coefficients, $K_{d_{pl}}$, were recalculated using the 1986 and 1987 hydrographic surveys and associated streamflow records as well as the data from 1985 and earlier used by Shields (1987). Table 8 presents the new values for the channel volume decay coefficients along with the previously reported values. All values have been multiplied by -100,000 for ease of comparison. The "no data" entry in Table 8 indicate that there were not enough survey data to calculate a constant.

54. The new decay coefficients show that with the exception of Denmon Creek, the bendways are continuing to fill at about the same rates as before or at slightly slower rates. In general, the projections made by Shields (1987) regarding future bendway volumes are apparently valid. James Creek and Big Creek bendways continued to fill during the period 1985-87 at about the same rates they did before 1985, despite the construction of blocks in 1985. Evidently, the tributaries to these bendways contributed most of the sediment that deposited in them between 1985 and 1987. Figure 7 shows that streamflow was extremely low during this period, so little if any sediment from the main channel entered either of the bends. A flood will undoubtedly have major impacts on many o^ the bendways.

55. The rather high decay coefficient for Columbus bendway is notable, particularly in light of the fact that some dredging has occurred there. A

Table 8

Comparison of Channel Volume Decay Coefficients Computed Using 1977-85 Data with Those Computed Using 1977-87 Data

Bendway	$-K_{d_{pl}} \times 10^5$ (Shields 1987)	New $-K_{d_{pl}} \times 10^5$ (1977-87 Data)	Percent Change
Rattlesnake Bend	3.40	3.32	-2.4
Cooks Bend	2.64	2.36	-10.6
Big Creek Bend*	3.78	3.11	-17.7
Hairston Bend	2.78	2.55	-8.3
Columbus Bend	No data	8.59	
Stinson Creek	2.82	2.46	-12.8
Town Creek	1.05	1.06	1.0
Buttahatchee River	2.43	2.21	-9.1
Vinton Creek	3.24	2.84	-12.3
Denmon Creek	2.65	3.28	23.8
Cane Creek	2.27	2.18	-4.0
McKinley Creek	4.65	4.91	5.6
Hickelson Lake	26.00	25.20	-3.1
James Creek	2.83	2.73	-3.7

* After 1981 dredging.

major flood may result in a large volume of deposition in this bendway. Furthermore, development that is currently occurring there will probably require the channel to be periodically maintained.

56. The 1986 and 1987 survey data were also used to compute cut channel growth coefficients, K_g (Shields 1987). Results are presented in Table 9. Negative values in Table 9 indicate that the cut is filling, while positive values indicate scour. The rate of cnange is related to the magnitude of the coefficients. In some cases, there are much larger differences between the growth coefficients based on 1977-87 data and those presented by Shields (1987) than for the bend decay coefficients. This is mainly because the bend decay coefficients presented by Shields (1987) were based on more adequate data than the cut channel growth coefficients.

57. In general, the recomputed channel growth constants indicate that the cuts in the upper portion of Columbus Lake are the only ones that are

Table 9

Comparison of Cut Channel Growth Coefficients Computed Using 1977-85 Data with Those Computed Using 1977-87 Data

Bendway	$-K_g \times 10^5$ (Shields 1987)	New $-K_g \times 10^5$ (1977-87 Data)	Percent Change
Rattlesnake Bend	0.09	0.20	117.7
Cooks Bend	1.07	0.87	-18.7
Big Creek Bend*	-0.02	0.04	-300.0
Hairston Bend	3.90	2.72	-30.3
Columbus Bend	No data	0.74	
Stinson Creek	-1.82	-1.33	-26.9
Town Creek	1.16	1.16	0.0
Buttahatchee River	0.55	0.50	-9.1
Vinton Creek	1.83	1.48	-19.1
Denmon Creek	0.21	0.37	76.2
Cane Creek	0.01	0.32	3,100.0
McKinley Creek	2.03	1.92	-5.4
Hickelson Lake	2.97	2.31	-19.5
James Creek	0.57	1.45	154.4

* After 1981 dredging.

scouring very rapidly. The magnitude of the scour in the upper portion of Columbus Lake is depicted in Figure 8, which is a plot of the mean bed elevation versus navigation mile (NM) in 1982, 1983, and August 1987. The left and right sides of the plot roughly correspond to the locations of Columbus and Aberdeen Locks and Dams, respectively. Mean bed elevations in the navigation channel adjacent to James Creek and Hickelson Lake bendways (NM 351.8-355.3) decreased 1 to 2 ft during this time period. Presumably, most of this scour was due to natural forces. However, dredging records provided by the TTW Management Center for 1986-87 (see Appendix A) indicate that 16,298 cu yd was dredged from the vicinity of NM 353.4 in 1986, and 115,129 cu yd was dredged from the vicinity of NM 353 in May 1987. This dredging was done to correct local shoaling (personal communication, 17 October 1988, Mr. Rick Saucer, TTW Management Center).

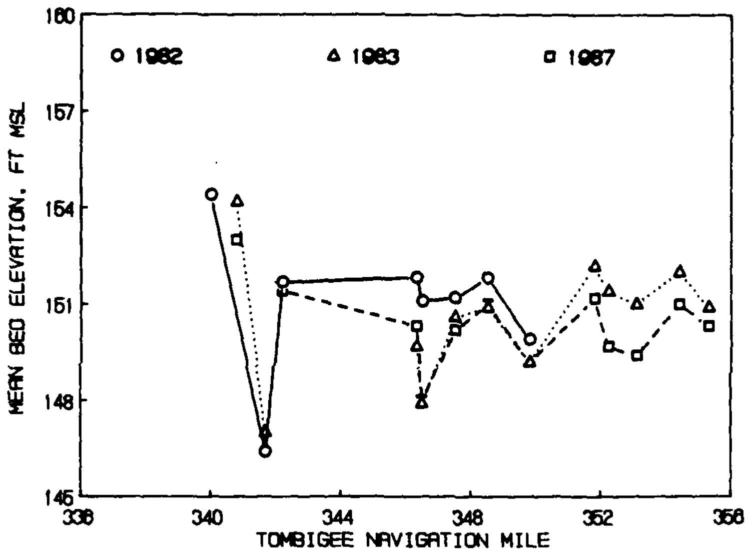


Figure 8. Mean bed elevation versus navigation mile for a portion of Columbus Lake

Observed deposition in each navigation lake

58. Demopolis Lake. Figure 9 (see page 43) depicts changes in Rattlesnake Bend, the only bendway in Demopolis Lake, between 1977 and 1987. The total volume of deposition increased rapidly for the first 6 years and more slowly thereafter. The apparent scour between 1984 and 1985 is probably the result of survey error. Little change in deposition volume occurred between 1986 and 1987, reflecting the extremely low flows during that period. Deposition has been greatest in the upper 3.5 miles of the bendway, decreasing the cross-sectional area by nearly 40 percent. The lower 6.5 miles of the bendway have experienced less deposition, but the cross-sectional area has still been reduced 10 to 15 percent. Cross-section surveys of two of the ranges in the extreme upstream portion of the bendway area are also shown in Figure 9. (All cross-section plots in this report are oriented facing downstream.) The pattern of deposition at range RB1 is typical of upstream bendway entrances. Significant deposition has occurred on the upstream side of the bend entrance, while the downstream entrance has eroded. (The RB1 plot shows 1986 rather than 1987 data because the 1987 data were not consistent with the earlier surveys. Apparently the range was moved slightly between 1986 and 1987.) Deposits at range RB2, located just downstream of RB1, are confined to the bed

of the old channel. The cross-section plots indicate that normal pool elevation does not influence the location of deposition. The magnitude of the deposition in Rattlesnake Bend is impressive in light of the fact that it is located deep in the reservoir pool.

59. Gainesville Lake. Figure 10 depicts results of hydrographic surveys of two of the seven bendways located in Gainesville Lake. The volume of deposition in Cooks Bend has been more than three times the volume deposited in Big Creek Bend, but virtually all of the deposition in Cooks Bend is below normal pool elevation and thus is invisible to observers. Mean depth in Cooks Bend based on the 1987 survey was still 16.6 ft, while mean depth in Big Creek Bend was only 4.4 ft. Significant deposition has occurred along the upper 2 miles of Cooks Bend, while very little deposition has occurred in the lower 1.7 miles. Plots of the two cross sections located closest to the upstream entrance show patterns similar to the Rattlesnake Bend sections shown in Figure 9, except that the bar on the upstream side of the bend entrance in Cooks Bend does not extend to top-bank elevation as in Rattlesnake Bend. The lower bar elevation for Cooks Bend is related to the more gradual angle between the cut channel and the bend entrance center lines. This angle is 42 deg for Cooks Bend, about half as great as the 90-deg angle for Rattlesnake Bend. Diversion angles near 90 deg promote deposition of a high, steep point bar at the bend entrance, while more gradual angles lead to formation of longer bars with more gradual side slopes.

60. Significant deposition has occurred all along the length of Big Creek Bend, with greatest effect in the reach just downstream of the upstream entrance. This reach was shallow with an emergent middle bar prior to bendway cutoff. The 1987 survey of range BCA shows that none of the cross section remains below normal pool elevation. Adjacent cross sections have experienced reductions of cross-sectional area of 50 to 80 percent. Actual deposition in Big Creek Bend may be greater than indicated by the calculations herein because much of the deposition from Big Creek occurs between survey ranges and thus goes undetected. Big Creek bendway was blocked in 1985, and the blockage embankment was eroded by high flows and subsequently repaired in 1987. When compared with the 1985 survey, the 1986 and 1987 surveys of the range closest to the upstream entrance (range BC) show evidence of excavation done to provide material for the blockage.

61. Aliceville Lake. Figure 11 shows results of hydrographic surveys of two of the four bendways located in Aliceville Lake. Hairston Bend has experienced steady deposition since it was cut off. The rate of deposition since 1985 is impressive, considering that flows have been rather low since then and that 30,527 cu yd was dredged from the upper 2,000 ft of the bendway in June and July 1987. This material was placed in the bend entrance to form a modified blockage structure, but the survey ranges coincide with the dredged area and not with the block. Deposition patterns at the two survey ranges closest to the upstream entrance (12HB and 11HB) have been somewhat similar to those observed at Cooks Bend. Hairston Bend has a diversion angle of about 46 deg. Almost all of the deposition in Hairston Bend has occurred in two short segments of the bend: in the upper mile and in a segment between points about 0.5 mile and 1.5 mile upstream from the downstream entrance.

62. Prior to cutoff, Columbus Bend was scoured by high flows in 1983. Since cutoff in 1984, Columbus Bend has experienced rapid deposition. Deposition in Columbus Bend is unusual in that it has occurred fairly uniformly along the length of the bend rather than being concentrated in the upper end. Although the Corps has not dredged Columbus Bend since cutoff, considerable commercial and industrial development is occurring along it. Volumes of material dredged from or placed in the bendway to support the development are unknown. Also, the effects of these activities or associated navigation traffic on the hydrographic survey ranges and thus the volumes presented herein are unknown. Deposition patterns for the two survey ranges closest to the upstream entrance (13B and 12B) are dissimilar to similarly located ranges for other bendways; deposition has occurred fairly uniformly across the channel bed since cutoff at both ranges.

63. Columbus Lake. Nine of the 18 bendways in Columbus Lake have been surveyed (see Figures 12-14). Results for three of these are depicted in Figure 12. Since there were only four survey ranges in Stinson Creek bendway and only five in Town Creek bendway, the measured channel volumes for these bendways and for Cane, Denmon, and Vinton Creek bendways (three ranges each) tended to be less accurate than for longer bendways with more ranges. Apparent scour for Stinson Creek bendway between 1983 and 1984, for Town Creek between 1983 and 1985, and for Buttahatchee River bendway between 1983 and 1984 is probably the result of survey inaccuracy, although some scour could have occurred during the high flows that occurred in 1983 and 1984. Most of

the deposition in Buttahatchee has occurred along the upper half of the bendway, but deposition has been distributed more uniformly along the two shorter bendways. Plots of cross sections in the upper ends of Stinson Creek and Buttahatchee River bendways show deposition on the upstream side of the bend entrance; the plot of range 19A at the upstream entrance of Town Creek shows the effects of navigation channel dredging because this range extends across both the bendway and the navigation cut, which are nearly parallel to each other at this location. The elevations of the sandbars in these three bend entrances reflect the relative magnitudes of their diversion angles. Diversion angles are roughly 30, 55, and 80 deg for Town, Stinson, and Buttahatchee, respectively.

64. Figure 13 shows results of surveys of Vinton, Denmon, and Cane Creek bendways. Deposition occurred most rapidly between 1981 and 1983, immediately after cutoff and during a period of high streamflow. All three of the survey ranges in Denmon Creek show significant scour between the initial survey in April 1981 and the first resurvey in December 1982. The reason for this scour is not known with certainty, but it could have been caused by flow acceleration due to completion of the cut channels just downstream prior to completion of the Denmon Creek cut. Blockage structures were constructed in the upstream bend entrances of each of these bendways shortly before the 1987 survey. Plots of the 1987 survey of the range nearest the upstream entrance for each of the bendways show the blocks in place in 1987. Survey ranges 41A and 36A coincide with sloping portions rather than the crest of the block.

65. Effects of deposition in McKinley, Hickelson Lake, and James Creek bendways are shown in Figure 14. McKinley and James filled gradually between 1981 and 1987, while Hickelson Lake, which receives sediment from a surface mine, was virtually filled prior to the October 1983 survey. McKinley and James Creek each had about two thirds of their original volume below normal pool elevation remaining in September 1987. Deposition in these bendways was greatest in the three-fourths mile just below the upstream entrance. Range 43A in James Creek, which is immediately upstream of the downstream entrance, was scoured between April 1981 and September 1983, but remained fairly constant between 1983 and 1987.

66. About 60,000 cu yd of deposition was measured in McKinley Creek bend between September 1986 and September 1987 despite the fact that 87,381 cu yd was dredged from the upper 3,500 ft of the bend in July and

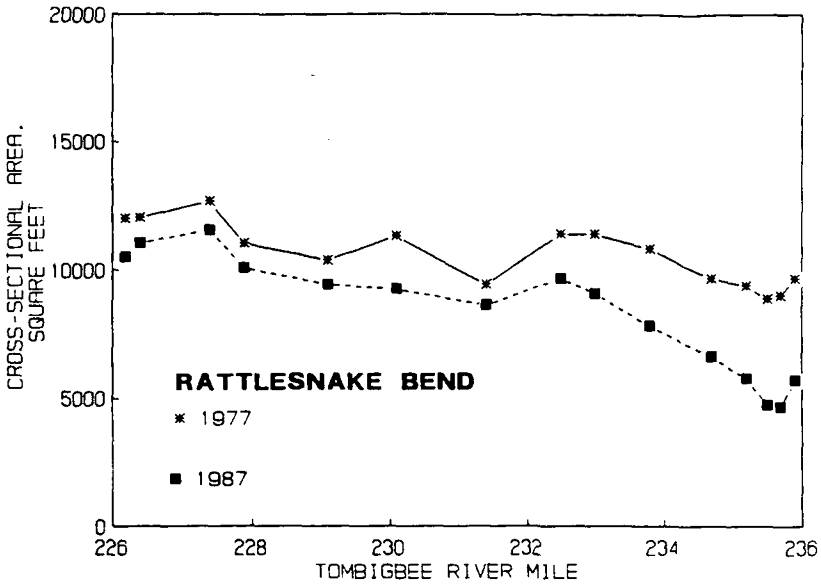
August 1987. Plots of surveys of ranges 54A and 53A show that while the 1987 dredging did restore a channel 6 to 8 ft deep for recreational craft, the original channel depth was not restored. Plots of the two ranges located closest to the upstream entrance of James Creek bendway (78A and 77A) show that this reach of the channel had been filled above normal pool elevation as early as October 1983. The natural blockage of the upper end of James Creek bendway probably reduced deposition of sediments from the main channel in the middle and lower portions of the bendway between the fall of 1983 and completion of the blockage embankment in the upstream entrance in the summer of 1985.

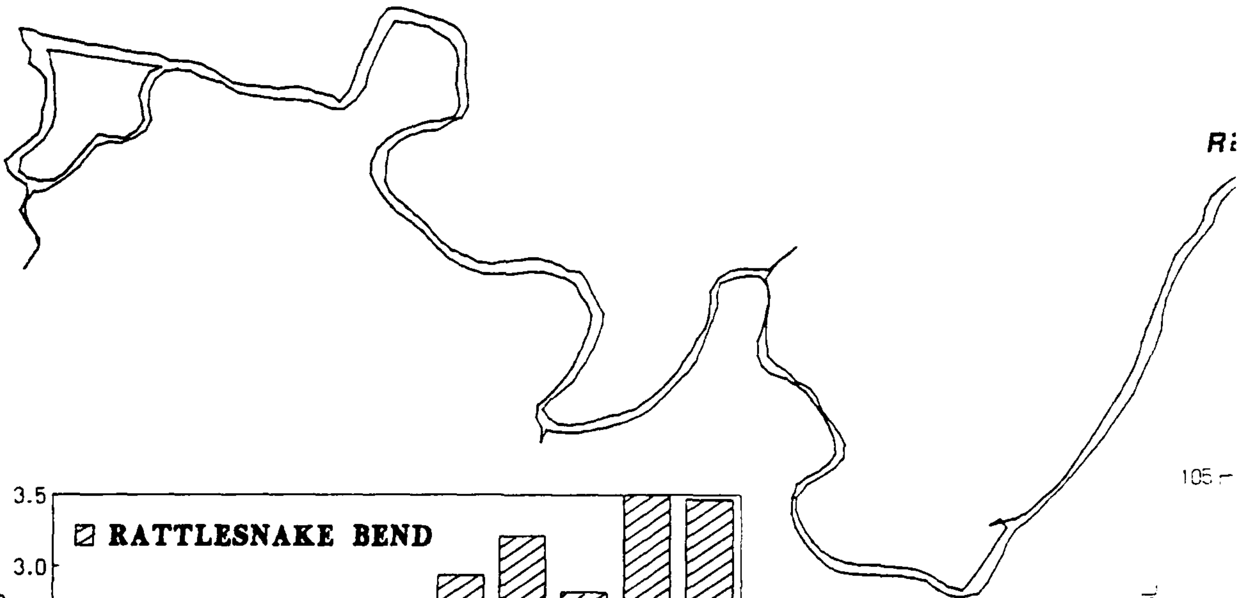
67. Aberdeen Lake. Analysis of physical changes in the eight cutoff bendways in Aberdeen Lake is not currently possible because there are too few sediment ranges in those bendways to compute channel volumes and deposition volumes. Furthermore, many of the existing ranges are located at oblique angles rather than right angles to the old channel. New ranges were established in Aberdeen Lake in 1988 to provide more adequate coverage of the bendways. The original ranges provide partial coverage for five of the eight bendways. Examination of plots of the 1984-87 surveys of these ranges is summarized in Table 10.

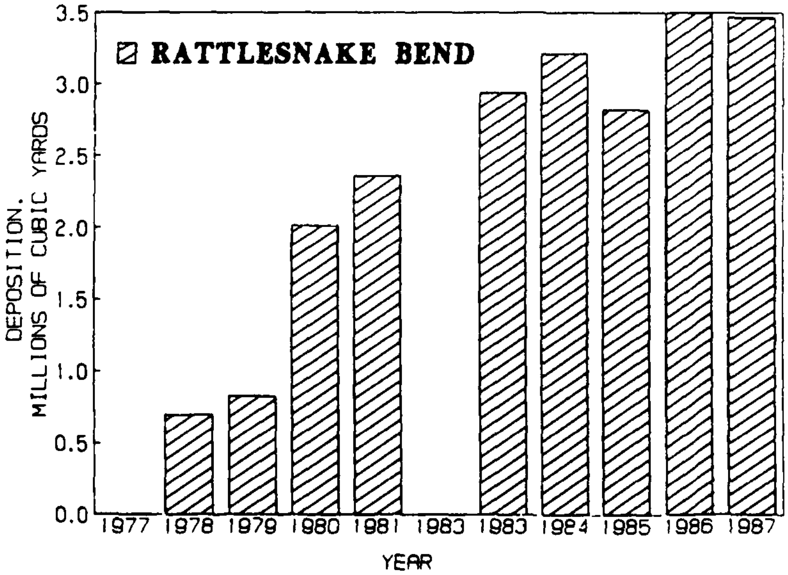
Table 10

Observed Changes in Aberdeen Lake Bendways, 1984-87

Bendway	Approximate Location of Upstream Entrance, TTW Navigation Mile	Approx. Bendway Length miles	Survey Range	Location of Range in Bend	Maximum Deposition ft
Roundhouse	366.2	0.6	None		
Becker	365.5	0.3	None		
Weaver Creek	365.2	0.5	11A	Middle	10
Drummond Branch	364.5	1.8	10AB	Upper	8
Un-named	363.6	0.6	9A	Middle	10
Acker Lake	363.0	2.1	8A	Middle	4
Un-named	360.6	1.1	6A	Upper	5
Un-named	359.6	0.8	None		







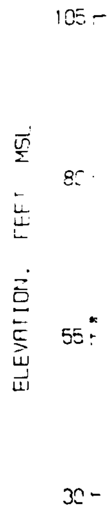
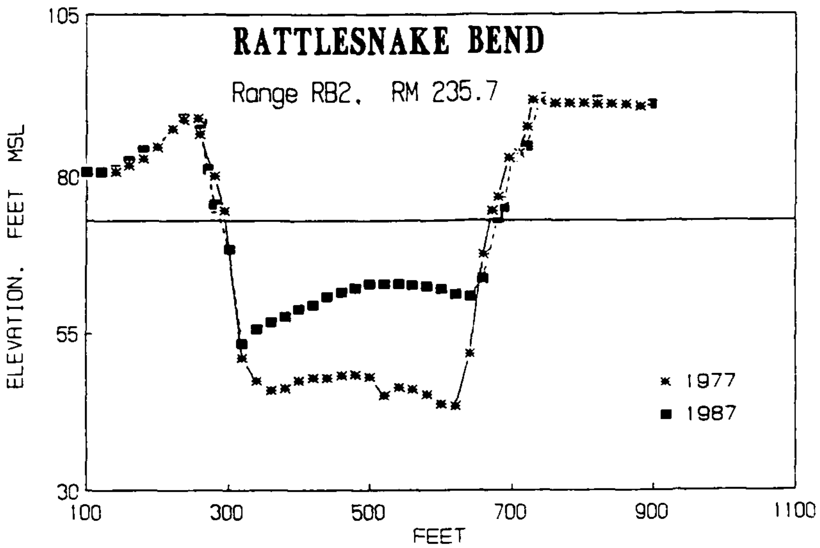
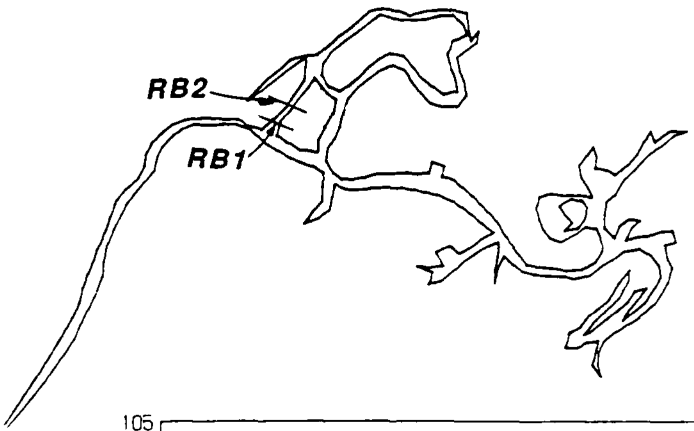
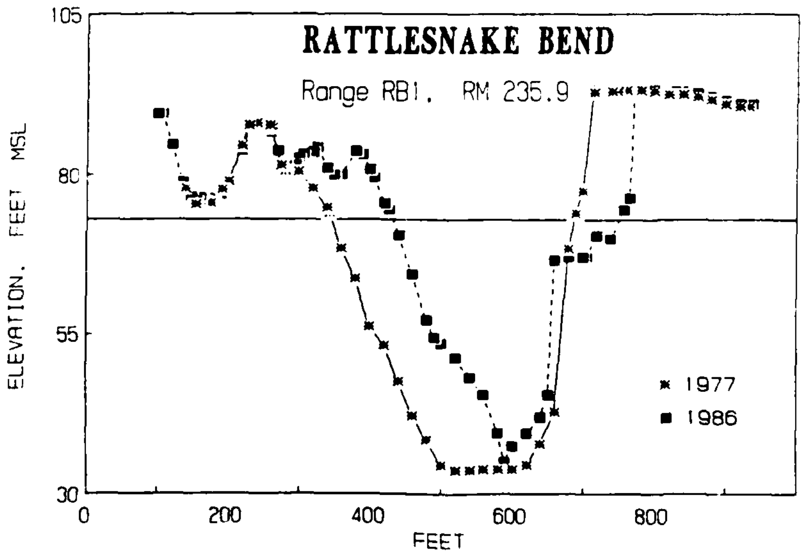


Figure 9. Bendway sedimentation, Demopolis Lake (horiz
on cross-section plots is at normal pool elevati







ke (horizontal line
i elevation)

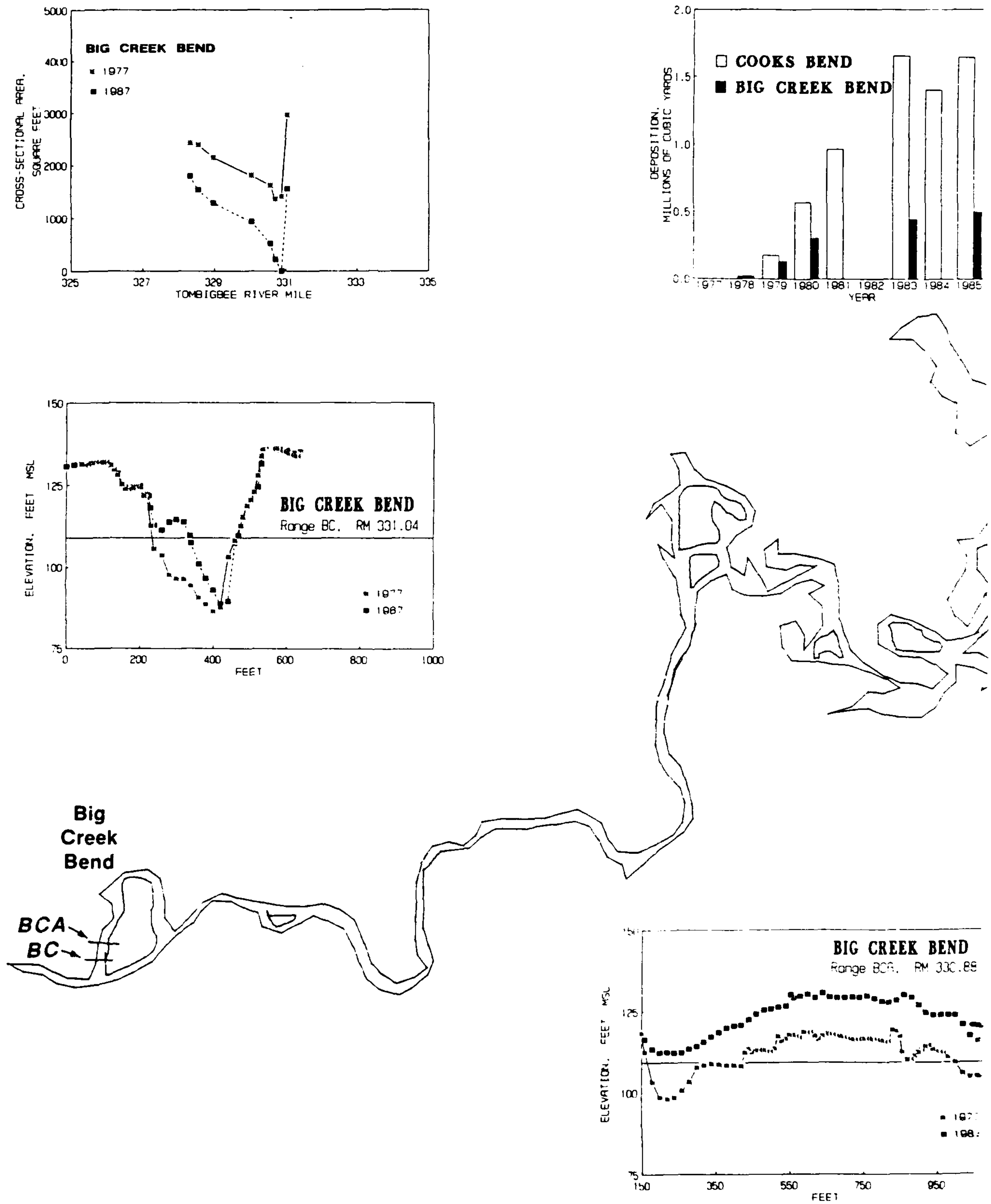
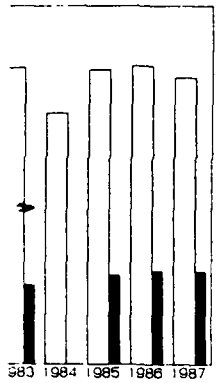
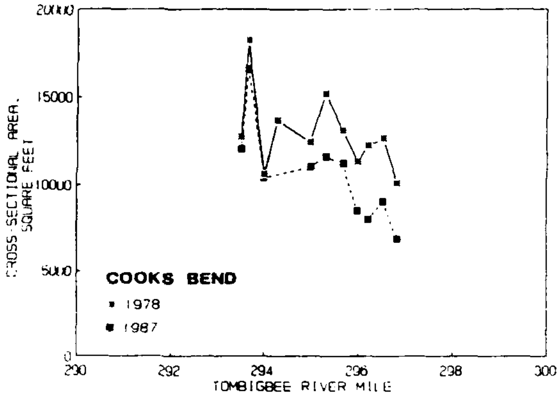
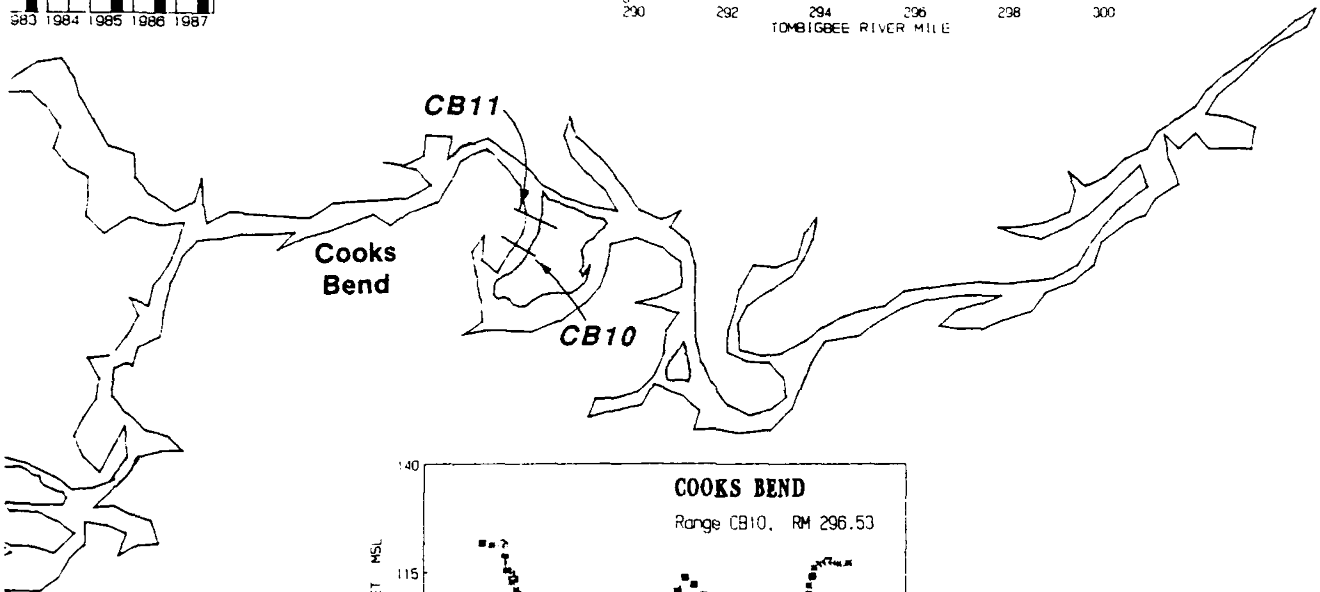
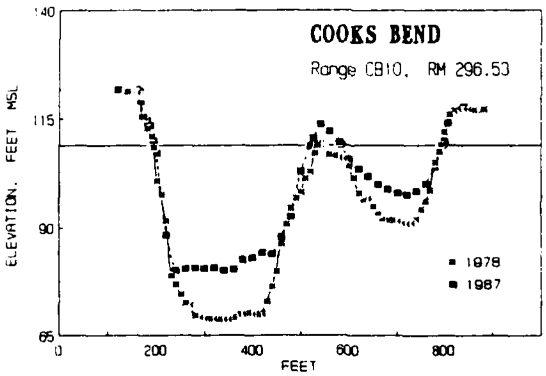


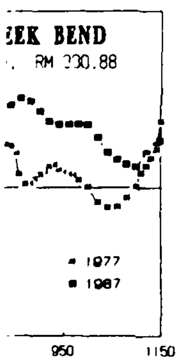
Figure 10. Bendway sedimentation,
on cross-section plots is

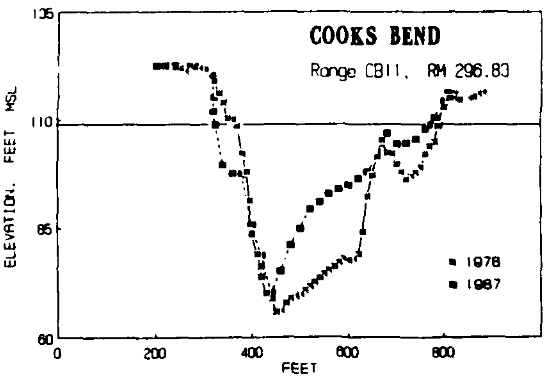












ition, Gainesville Lake (horizontal line
ots is at normal pool elevation)

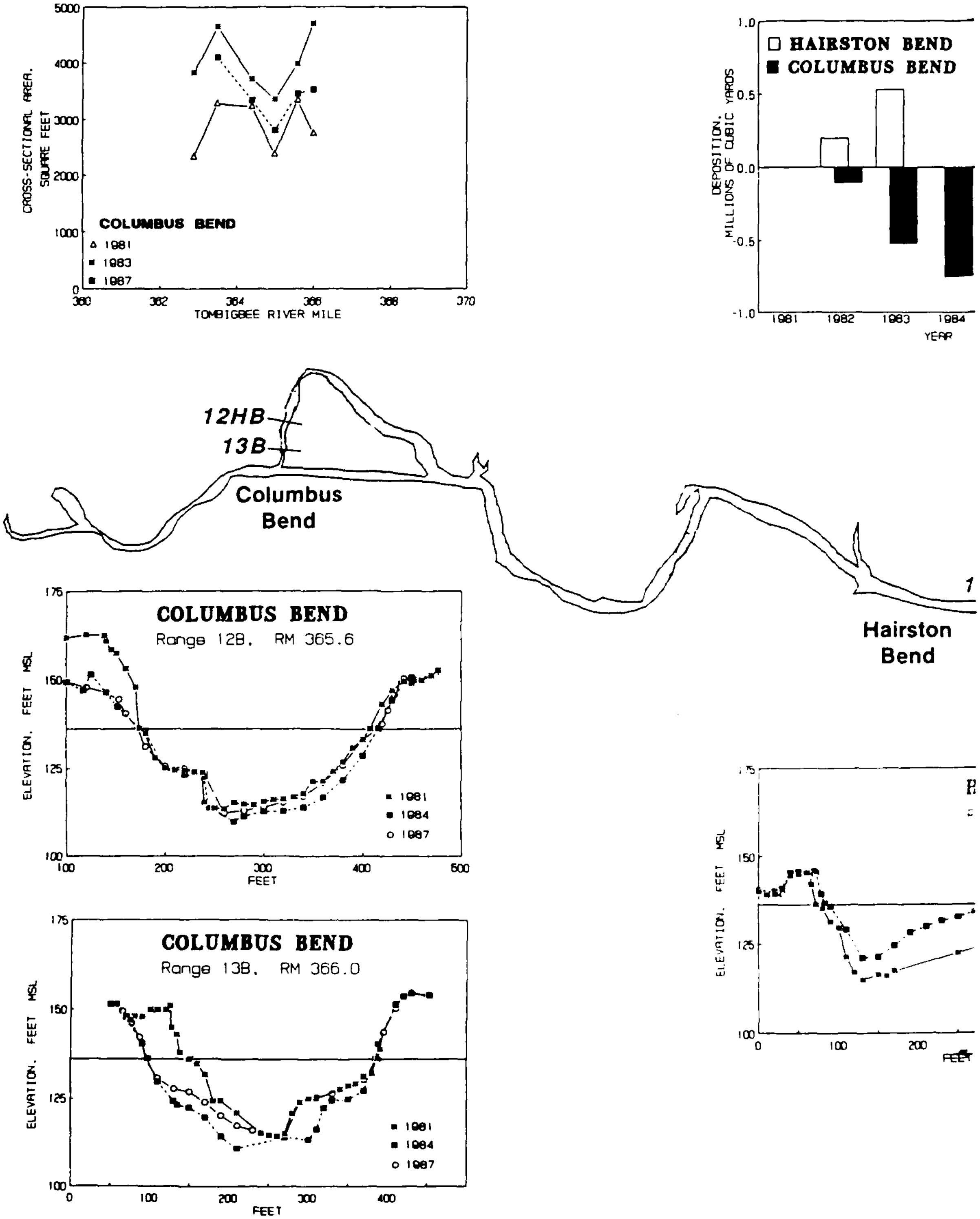
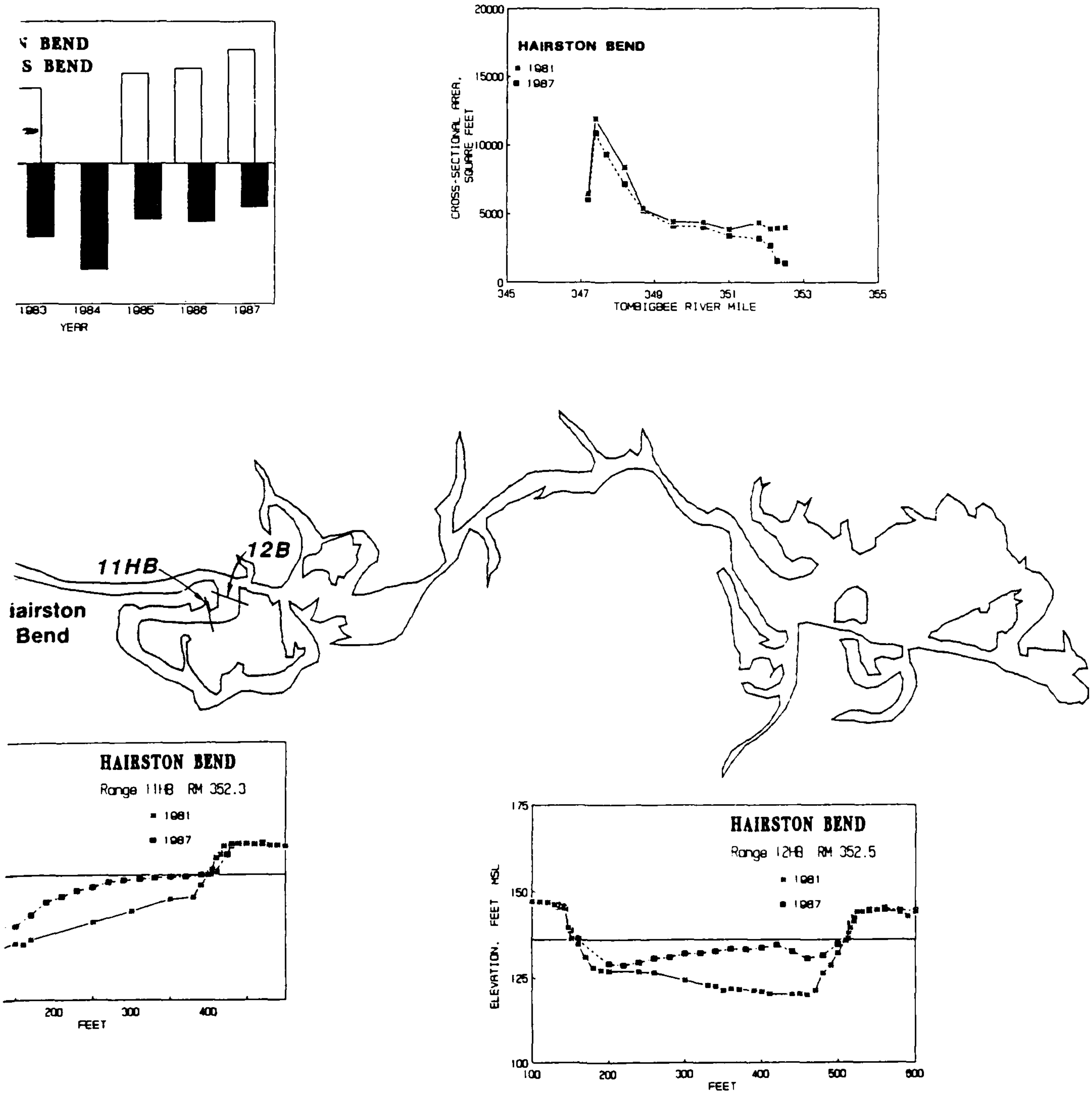


Figure 11. Bendway sedimentation, Al:
on cross-section plots is at :



ation, Aliceville Lake (horizontal line
ts is at normal pool elevation)

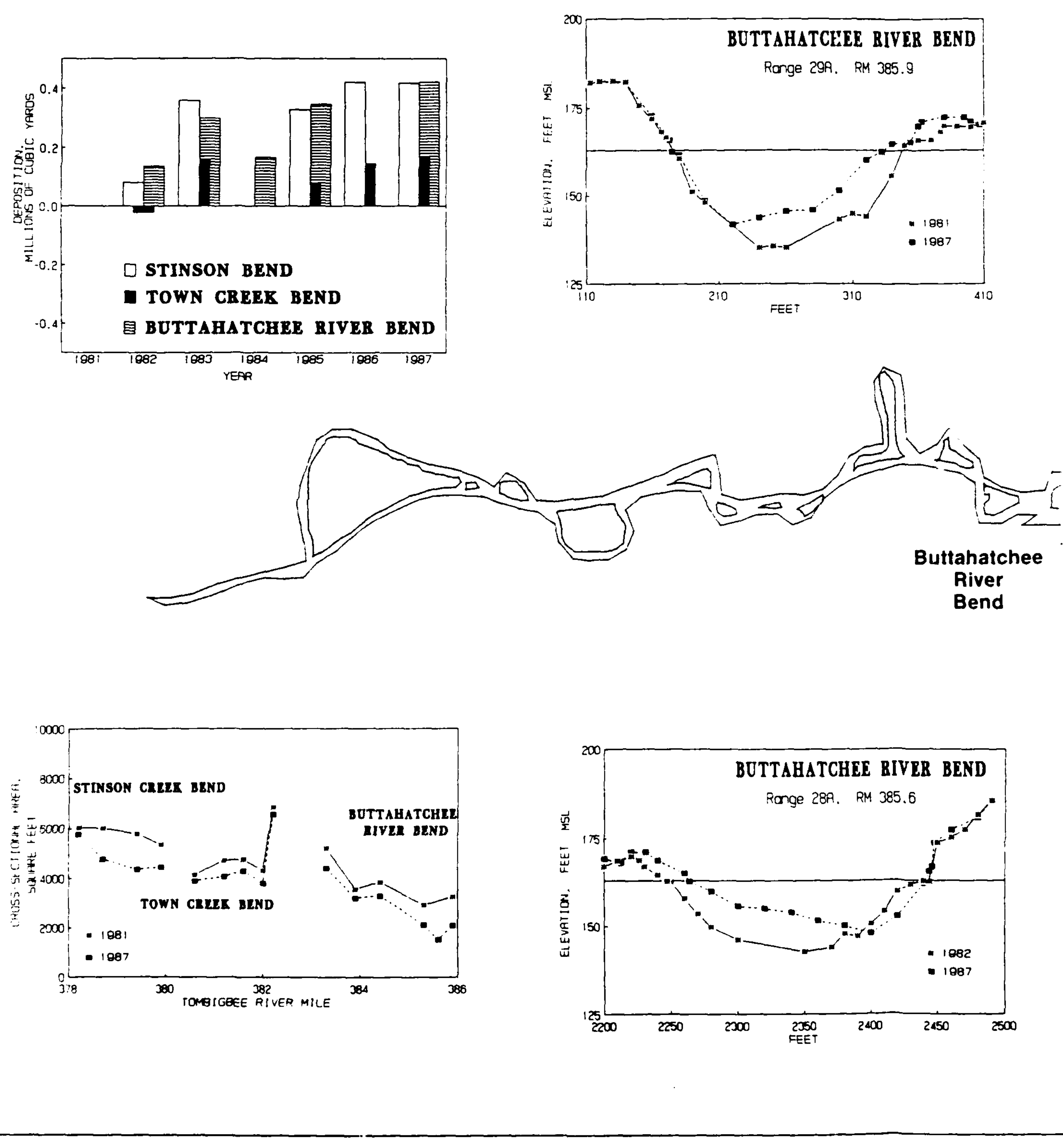
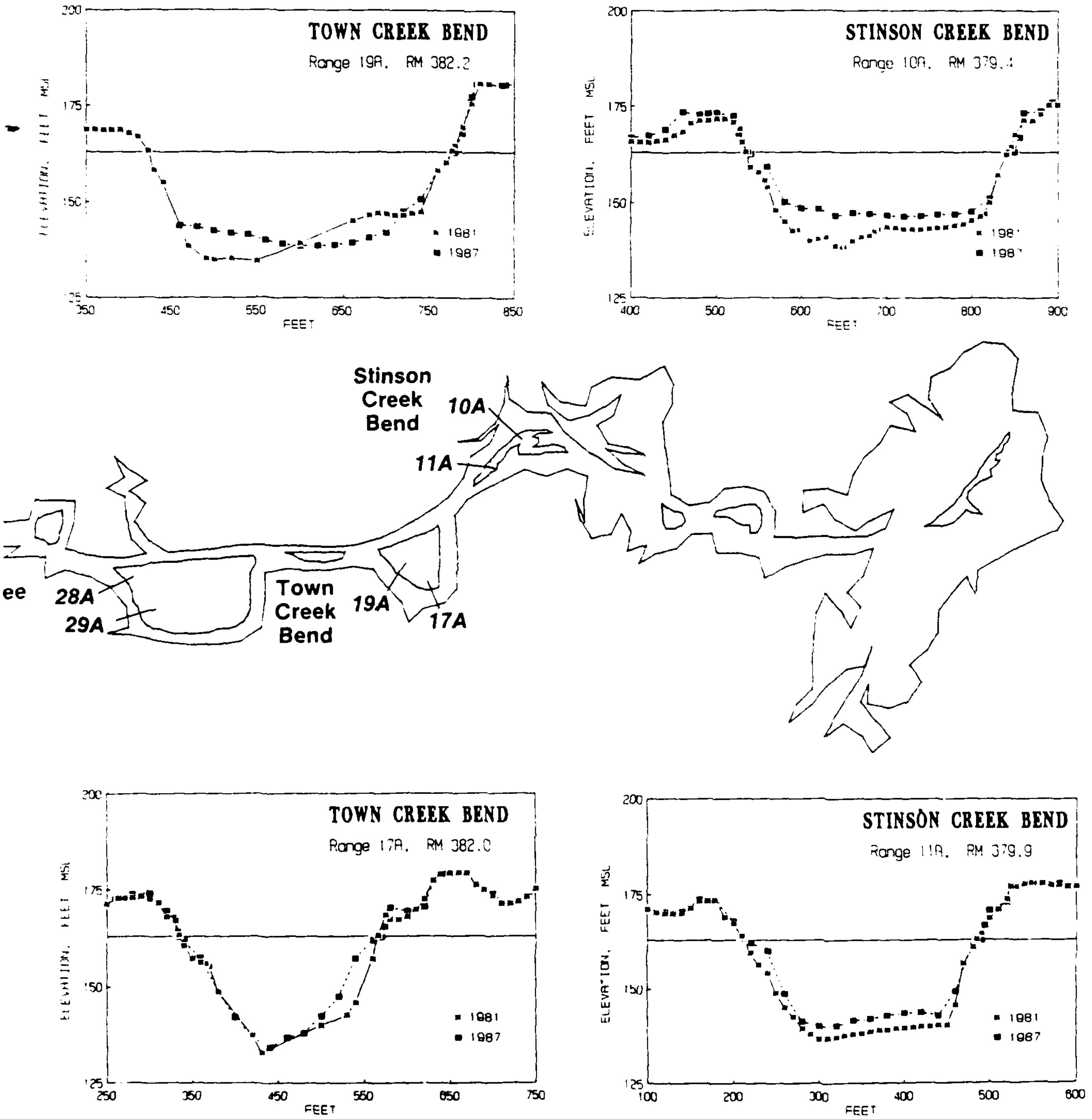


Figure 12. Bendway sedimentation, Colur
and Buttahatchee River). Horizontal lir
normal pool ele



Columbus Lake (Stinson and Town Creeks
al line on cross-section plots is at
ol elevations

2 of 2

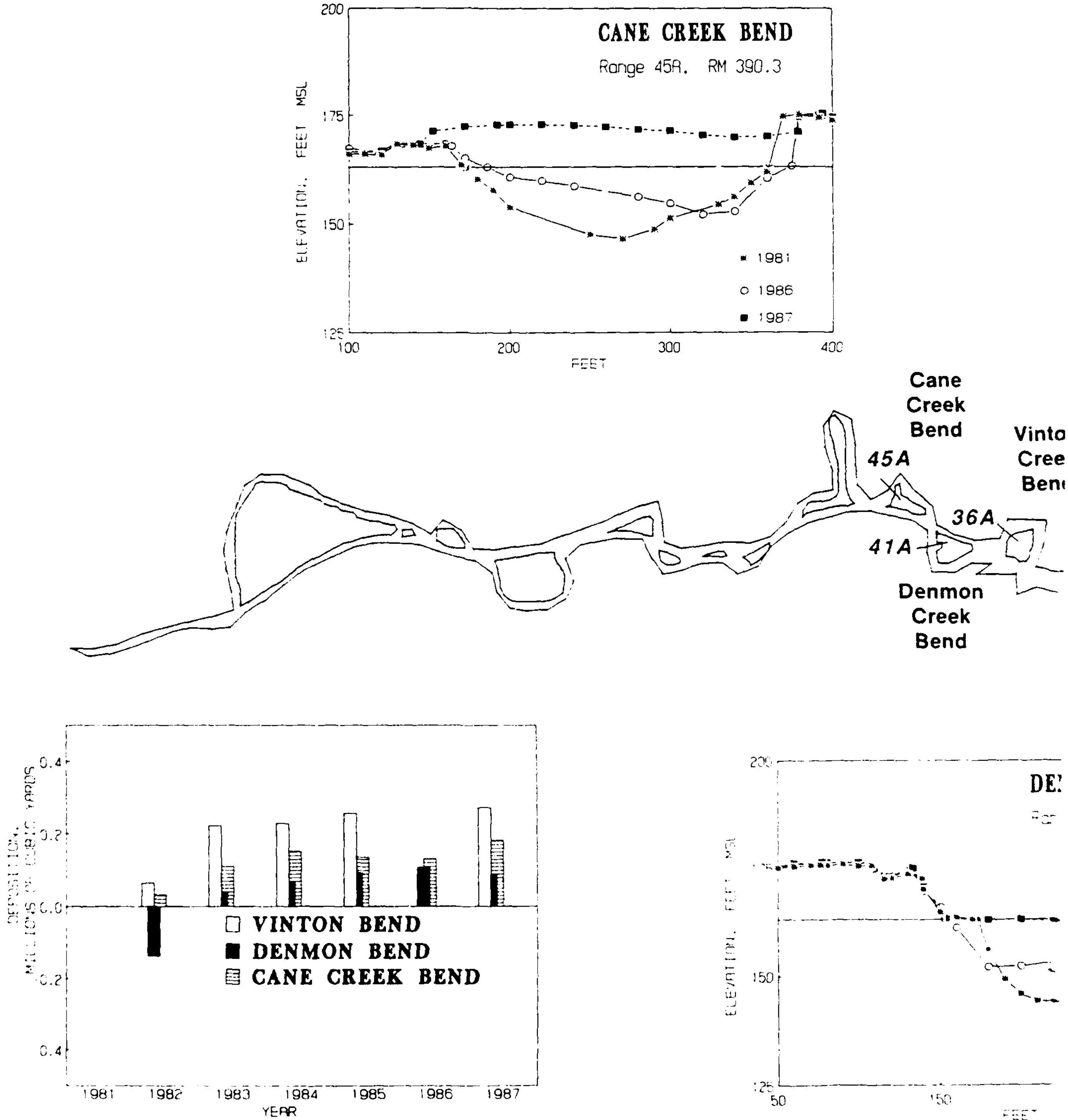
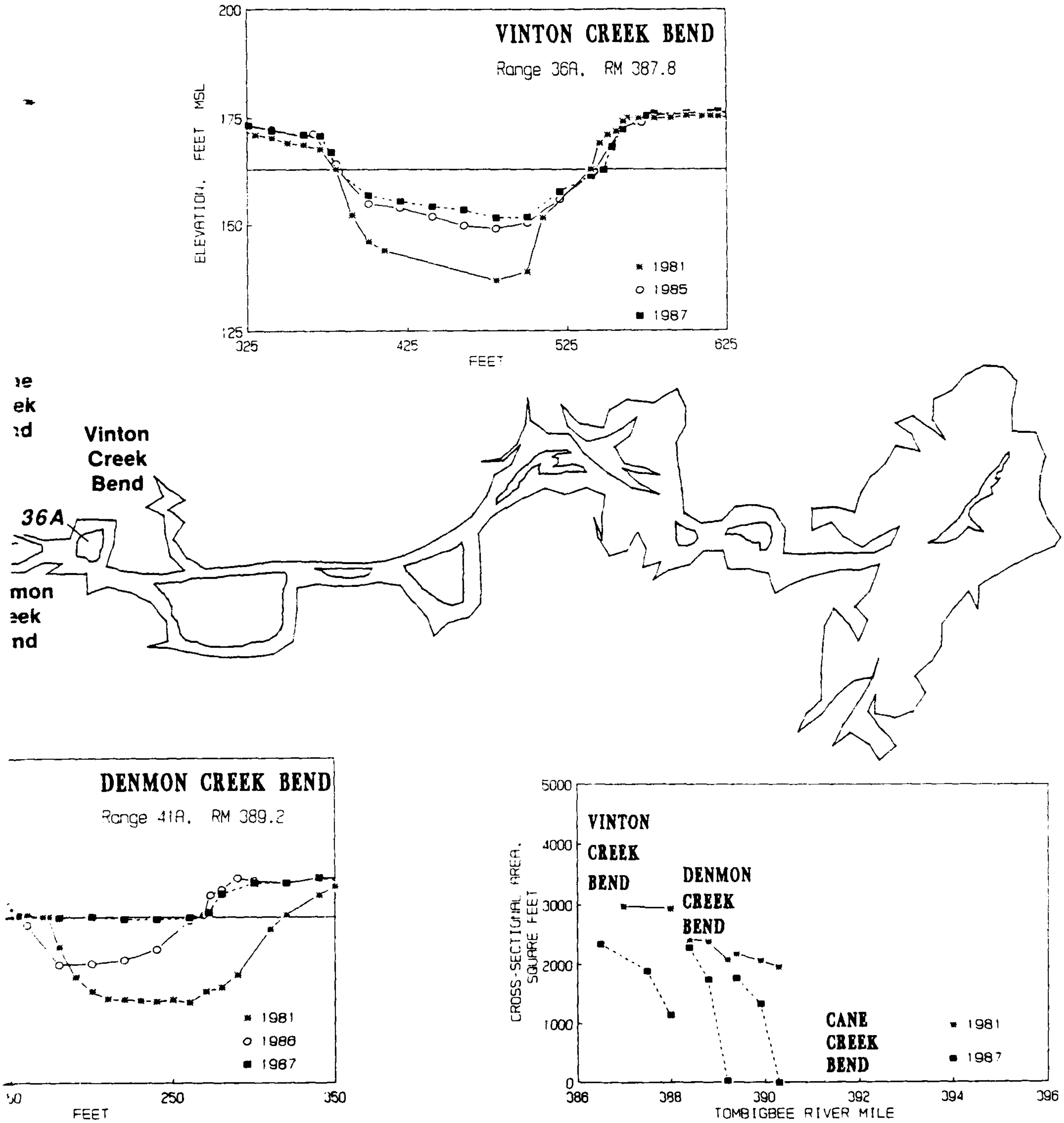


Figure 13. Bendway sedimentation, Col
Cane Creeks). Horizontal line on cros
elevatio



ation, Columbus Lake (Vinton, Denmon, and
ne on cross-section plots is at normal pool
elevation

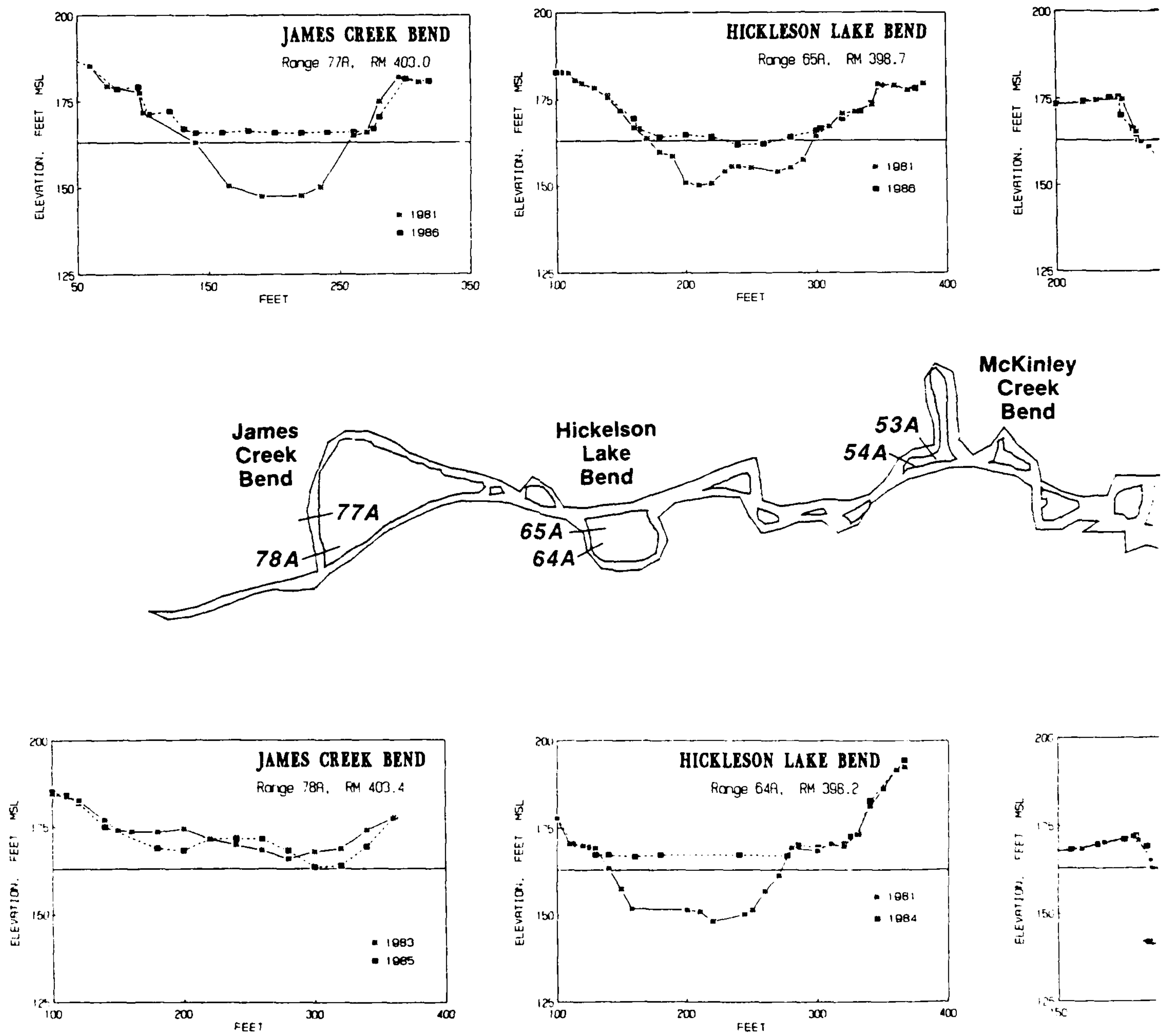
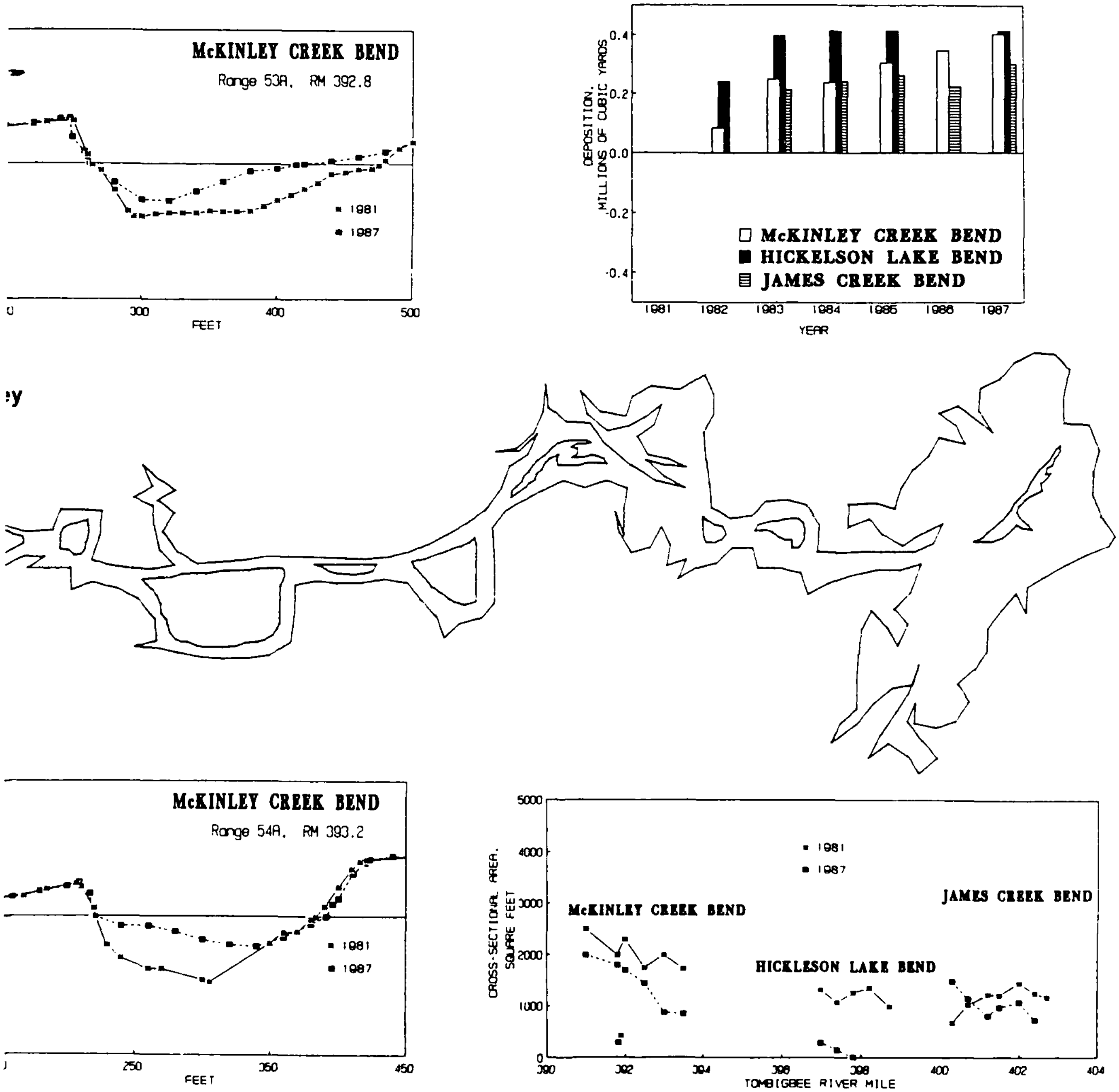


Figure 14. Bendway sedimentation,
Hickelson Lake, and James Creek).
plots is at normal



ation, Columbus Lake (McKinley Creek,
eek). Horizontal line on cross-section
normal pool elevation

General Infilling Phase Results

68. Photo coverage of the 26 sites was found for periods ranging from 12 to 51 years. A listing of the photos that were used to obtain data is presented as Table A4 of Appendix A. Maps corresponding to tree lines depicted on selected photo coverages of each site are presented in Appendix B. Results of these measurements are presented in Table 11 and in Figures 15-17. Tree line-enclosed area (A) was actually larger at the latest observation than at the initial observation (A_i) for 13 of the sites. Increases in area were due to the construction of small dams or embankments at one end of the oxbow or bendway for five sites (T4, 01, 01.5, 02, and BW1) and to the closure of navigation dams on the master stream for seven sites (T2, A3, A6, 03, 04, BW2, and BW3). The one remaining site (A13) experienced only a 1.5-acre increase in area; this was probably due to measurement error.

69. Tree line length (lake perimeter, P) increased over the period of observation at 16 of the 26 sites. The shoreline development index increased at 13 of the sites. Both perimeters and SDIs tended to vary less through time than did area. The stability of tree line perimeter is shown in Figures 15-17. Tree line length generally did not decrease with decreasing area because tree lines become more complex as lakes grow smaller. The figures in Appendix B show that the tree lines developed islands and peninsulas, and sometimes lakes became two or more distinct water bodies (based on tree line) as overall area declined. A frequency histogram for SDI is presented as Figure 18. The SDI values were fairly high, reflecting the noncircular, sinuous shapes of the bendways and oxbow lakes studied. Seventy-eight percent of the SDI values were 3.53 or greater.

70. Changes in area following increases in lake water level due to dam closure (both small embankments or main-channel navigation dams) were almost always gradual. Except for perhaps site T2, clearing did not precede impoundment, and flooded trees gradually died and decayed, leading to gradual increases in tree line-enclosed area. These processes were evident at many of the sites when successive aerial photos were examined. In a similar but less pronounced fashion, declines in tree line-enclosed area gradually followed sediment deposition as pioneer species invaded formerly inundated areas. "Static" or "noise" (small variations) in curves of area versus time are

Table 11
Infilling Phase Data - Enclosed Area and Perimeter of Tree Lines

Site*	Date	Area acres	Perimeter ft	A/A_i	P/P_i	Shoreline Development Index
T2	02 Dec 37	91.0	3.47 E+04	1.000	1.000	4.9
T2	15 Nov 49	36.2	3.31 E+04	0.398	0.955	7.4
T2	19 Dec 59	37.3	3.21 E+04	0.410	0.926	7.1
T2	01 Dec 65	37.9	3.68 E+04	0.417	1.061	8.1
T2	14 Oct 79	42.8	3.48 E+04	0.470	1.004	7.2
T2	17 Oct 86	185.1	4.45 E+04	2.034	1.283	4.4
T3	30 Sep 37	40.9	1.25 E+04	1.000	1.000	2.6
T3	05 Feb 52	44.7	1.38 E+04	1.093	1.106	2.8
T3	16 Nov 63	38.7	1.32 E+04	0.946	1.056	2.9
T3	16 Oct 86	38.0	1.29 E+04	0.929	1.037	2.8
T4	27 Sep 37	9.9	1.34 E+04	1.000	1.000	5.7
T4	05 Feb 52	13.6	1.61 E+04	1.368	1.201	5.9
T4	11 Nov 58	12.7	1.44 E+04	1.278	1.074	5.5
T4	22 Mar 69	14.0	1.42 E+04	1.407	1.061	5.1
T4	15 Sep 72	15.5	1.78 E+04	1.559	1.329	6.1
T4	16 Oct 86	15.9	1.68 E+04	1.600	1.259	5.7
A1	20 Aug 40	173.6	3.37 E+04	1.000	1.000	3.5
A1	05 Nov 49	162.3	3.43 E+04	0.935	1.017	3.6
A1	04 Nov 55	99.3	2.64 E+04	0.572	0.783	3.6
A1	08 Oct 65	100.2	2.81 E+04	0.577	0.833	3.8
A1	19 Jan 73	147.1	3.03 E+04	0.847	0.898	3.4
A1	04 Apr 75	133.7	3.30 E+04	0.770	0.979	3.9
A1	07 Feb 83	166.8	3.27 E+04	0.961	0.970	3.4
A3	12 Jul 58	29.5	6.18 E+04	1.000	1.000	15.4
A3	08 Oct 64	26.3	4.36 E+04	0.892	0.706	11.5
A3	22 Mar 72	25.8	3.94 E+04	0.875	0.638	10.5
A3	20 Jul 84	32.8	5.23 E+04	1.112	0.846	12.3
A6	14 Mar 72	739.9	8.79 E+04	1.000	1.000	4.4
A6	09 Dec 77	824.8	7.38 E+04	1.115	0.840	3.5
A6	09 Feb 87	859.6	6.32 E+04	1.162	0.719	2.9
A8	18 Sep 56	420.0	4.18 E+04	1.000	1.000	2.8
A8	13 Feb 62	262.6	5.07 E+04	0.625	1.213	4.2
A8	08 Feb 87	155.1	5.56 E+04	0.369	1.329	6.0

(Continued)

* Site locations and descriptions are given in Figure 3 and Table 3.

(Sheet 1 of 4)

Table 11 (Continued)

Site	Date	Area acres	Perimeter ft	A/A_i	P/P_i	Shoreline Development Index
A9	12 Nov 58	1,507.0	6.63 E+04	1.000	1.000	2.3
A9	08 Oct 65	79.2	6.77 E+04	0.053	1.020	10.3
A9	19 Sep 68	89.4	6.39 E+04	0.059	0.963	9.1
A9	19 Mar 69	871.0	1.02 E+05	0.578	1.530	4.6
A9	19 Jan 73	842.0	1.10 E+05	0.559	1.660	5.1
A9	21 Oct 75	919.8	1.10 E+05	0.610	1.661	4.9
A9	08 Jan 84	1,051.5	1.27 E+05	0.698	1.907	5.3
A10	08 Oct 55	315.9	8.29 E+04	1.000	1.000	6.3
A10	01 Dec 60	246.6	4.84 E+04	0.781	0.584	4.2
A10	03 Oct 64	187.0	3.68 E+04	0.592	0.444	3.6
A10	12 Oct 66	178.0	3.55 E+04	0.563	0.428	3.6
A10	26 Oct 71	200.0	5.02 E+04	0.633	0.605	4.8
A10	29 Jan 73	205.4	4.81 E+04	0.650	0.580	4.5
A11	13 Jun 63	396.0	4.46 E+04	1.000	1.000	3.0
A11	20 Feb 65	163.8	4.94 E+04	0.414	1.106	5.2
A11	25 Oct 66	160.0	4.69 E+04	0.404	1.051	5.0
A11	17 Dec 72	223.0	4.46 E+04	0.563	0.998	4.0
A11	13 Nov 75	244.0	5.51 E+04	0.616	1.236	4.8
A11	23 Dec 81	223.2	5.58 E+04	0.564	1.251	5.0
A12	10 Nov 60	316.0	4.18 E+04	1.000	1.000	3.2
A12	29 May 63	291.0	4.17 E+04	0.921	0.997	3.3
A12	10 Sep 68	60.8	3.28 E+04	0.192	0.786	5.7
A12	27 Dec 72	29.0	3.08 E+04	0.092	0.737	7.7
A13	22 Mar 72	24.0	1.11 E+04	1.000	1.000	3.0
A13	20 Jul 84	25.5	1.12 E+04	1.063	1.015	3.0
R1	07 Nov 63	139.7	3.97 E+04	1.000	1.000	4.5
R1	29 Nov 69	129.3	3.96 E+04	0.926	0.996	4.7
R1	09 Nov 78	88.3	4.07 E+04	0.632	1.024	5.9
R2	29 Dec 56	228.1	3.62 E+04	1.000	1.000	3.2
R2	26 Mar 62	158.9	3.72 E+04	0.697	1.029	4.0
R2	15 Oct 68	136.0	4.05 E+04	0.596	1.119	4.7
R2	27 Jan 75	125.1	4.22 E+04	0.548	1.166	5.1
R2	22 Feb 82	92.6	2.62 E+04	0.406	0.725	3.7
O1	18 Sep 40	88.0	2.44 E+04	1.000	1.000	3.5
O1	04 Sep 52	96.3	2.70 E+04	1.094	1.107	3.7
O1	19 Oct 59	212.2	3.62 E+04	2.411	1.486	3.4
O1	28 Nov 66	245.4	3.91 E+04	2.789	1.604	3.4
O1	27 Sep 85	234.3	3.69 E+04	2.663	1.514	3.3

(Continued)

(Sheet 2 of 4)

Table 11 (Continued)

Site	Date	Area acres	Perimeter ft	A/A_i	P/P_i	Shoreline Development Index
01.5	18 Sep 40	164.8	3.30 E+04	1.000	1.000	3.5
01.5	04 Sep 52	184.4	3.78 E+04	1.119	1.144	3.8
01.5	23 Oct 59	189.4	3.99 E+04	1.149	1.210	3.9
01.5	28 Nov 66	278.1	5.18 E+04	1.688	1.569	4.2
01.5	27 Sep 85	282.1	5.35 E+04	1.712	1.621	4.3
02	11 Oct 41	18.8	1.17 E+04	1.000	1.000	3.7
02	16 Jan 51	21.5	1.21 E+04	1.144	1.029	3.5
02	18 May 56	30.2	1.60 E+04	1.606	1.369	3.9
02	09 Jan 61	30.2	1.53 E+04	1.606	1.308	3.8
02	18 Nov 67	28.8	1.55 E+04	1.532	1.325	3.9
02	08 Feb 85	40.7	1.79 E+04	2.165	1.529	3.8
03	11 Nov 41	63.6	2.42 E+04	1.000	1.000	4.1
03	16 Jan 51	68.8	2.39 E+04	1.082	0.988	3.9
03	09 Jan 61	66.9	2.39 E+04	1.052	0.989	4.0
03	06 Nov 67	69.9	2.55 E+04	1.099	1.053	4.1
03	10 Feb 73	68.5	2.46 E+04	1.077	1.018	4.0
03	12 Feb 85	75.6	2.44 E+04	1.189	1.010	3.8
04	18 Sep 40	54.2	3.08 E+04	1.000	1.000	5.6
04	04 Sep 52	61.0	3.19 E+04	1.125	1.036	5.5
04	28 Nov 66	60.7	2.84 E+04	1.120	0.922	4.9
04	19 Feb 72	74.6	3.06 E+04	1.376	0.994	4.8
04	24 Jan 80	86.0	2.86 E+04	1.587	0.931	4.2
BW1	19 Oct 36	4.3	5.67 E+03	1.000	1.000	3.7
BW1	23 Feb 50	7.3	6.25 E+03	1.710	1.101	3.1
BW1	25 Apr 55	7.2	6.50 E+03	1.686	1.146	3.3
BW1	23 Oct 65	12.4	1.14 E+04	2.904	2.017	4.4
BW1	17 Nov 81	27.9	1.66 E+04	6.534	2.928	4.3
BW2	23 Feb 50	45.5	1.57 E+04	1.000	1.000	3.1
BW2	25 Apr 55	42.4	1.57 E+04	0.932	0.997	3.3
BW2	23 Oct 65	62.2	2.06 E+04	1.367	1.311	3.5
BW2	17 Nov 81	60.4	1.76 E+04	1.327	1.122	3.1
BW3	02 Nov 39	22.2	1.38 E+04	1.000	1.000	4.0
BW3	23 Feb 50	28.8	1.40 E+04	1.297	1.010	3.5
BW3	17 Oct 65	47.2	1.49 E+04	2.126	1.075	2.9
BW3	12 May 74	48.7	1.49 E+04	2.194	1.075	2.9
BW3	17 Nov 81	42.4	1.31 E+04	1.910	0.943	2.7

(Continued)

(Sheet 3 of 4)

Table 11 (Concluded)

Site	Date	Area acres	Perimeter ft	A/A_i	P/P_i	Shoreline Development Index
BW4	27 Nov 36	36.3	1.35 E+04	1.000	1.000	3.0
BW4	23 Feb 50	30.8	1.39 E+04	0.848	1.024	3.4
BW4	21 Mar 60	30.3	1.42 E+04	0.835	1.046	3.5
BW4	17 Nov 81	29.4	1.40 E+04	0.810	1.036	3.5
BW4	20 Sep 87	32.4	1.46 E+04	0.893	1.076	3.5
M1	07 Apr 50	4,559.4	1.88 E+05	1.000	1.000	3.8
M1	26 Feb 54	4,527.4	1.91 E+05	0.993	1.020	3.8
M1	06 Oct 57	4,011.8	2.13 E+05	0.880	1.137	4.5
M1	14 Nov 62	3,723.2	2.08 E+05	0.817	1.108	4.6
M1	26 Oct 66	3,573.8	2.12 E+05	0.784	1.130	4.8
M1	21 Nov 73	3,397.0	2.02 E+05	0.745	1.079	4.7
M1	25 Oct 79	4,025.0	2.04 E+05	0.883	1.088	4.3
M2	16 Nov 49	612.0	7.69 E+04	1.000	1.000	4.2
M2	17 Feb 57	290.0	7.31 E+04	0.474	0.952	5.8
M2	03 Nov 66	170.0	5.96 E+04	0.278	0.775	6.2
M2	01 Nov 73	183.0	5.94 E+04	0.299	0.773	5.9
M2	26 Oct 79	208.0	6.28 E+04	0.340	0.817	5.9
M2	29 Jan 84	257.0	6.36 E+04	0.420	0.828	5.4
M3	15 Jun 48	3,748.0	2.70 E+05	1.000	1.000	6.0
M3	18 Oct 59	1,774.0	1.84 E+05	0.473	0.680	5.9
M3	07 Oct 64	1,732.0	1.76 E+05	0.462	0.652	5.7
M3	15 Nov 69	1,708.0	1.78 E+05	0.456	0.657	5.8
M3	31 Oct 75	1,816.0	1.89 E+05	0.485	0.700	6.0
M3	07 Feb 77	1,952.0	2.14 E+05	0.521	0.791	6.5
M3	07 Mar 82	2,098.0	2.09 E+05	0.560	0.773	6.2

(Sheet 4 of 4)

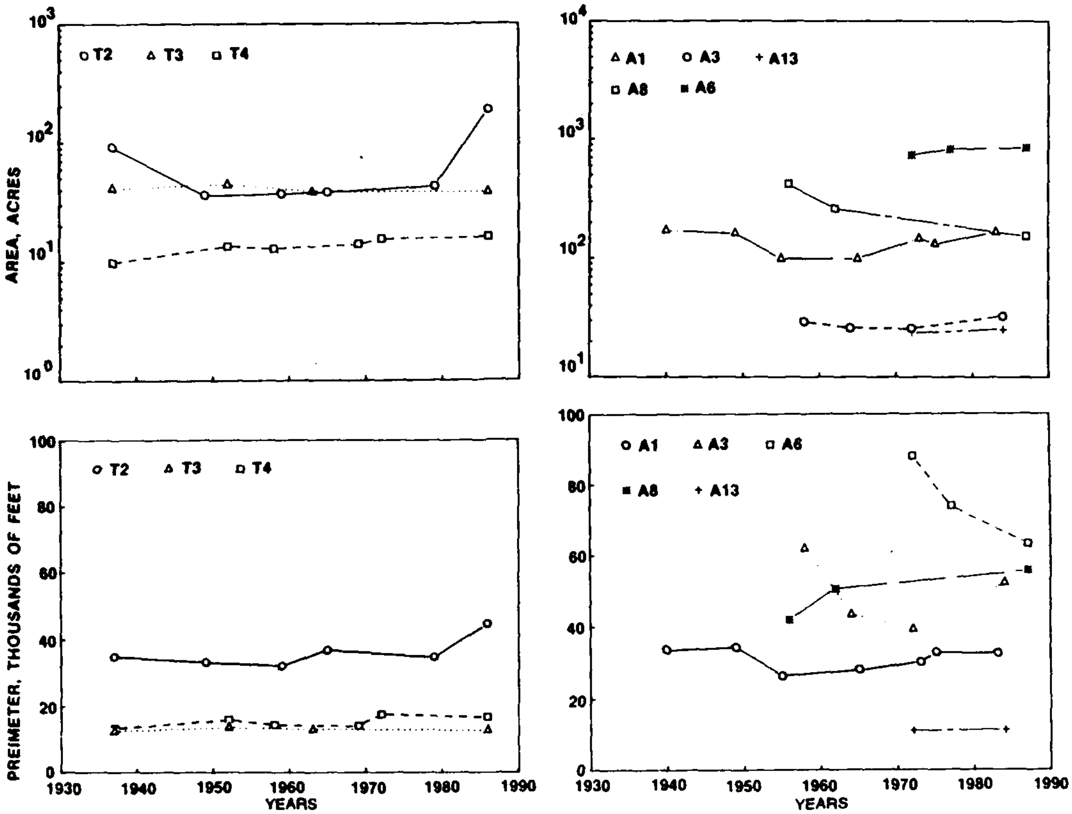


Figure 15. Tree line-enclosed area and perimeter, Tombigbee and Arkansas River sites

probably due to effects of climatic and hydrologic variations on the tree community as well as measurement errors.

Infilling Results by River System

Tombigbee River

71. Initially, four naturally formed oxbow lakes along the Tombigbee River were selected for study. However, one of the four (an old meander scar located just northwest of Gainesville, AL) was eliminated from further consideration when examination of the oldest available photos revealed that it entered the terrestrial phase before the earliest photos were taken. Although the meander scar itself shows up on the photos due to a change in the hue of the vegetation, no open area within the tree line is visible, even in the 1937 coverage. The remaining three oxbows were the natural cutoff at Lubbub Creek,

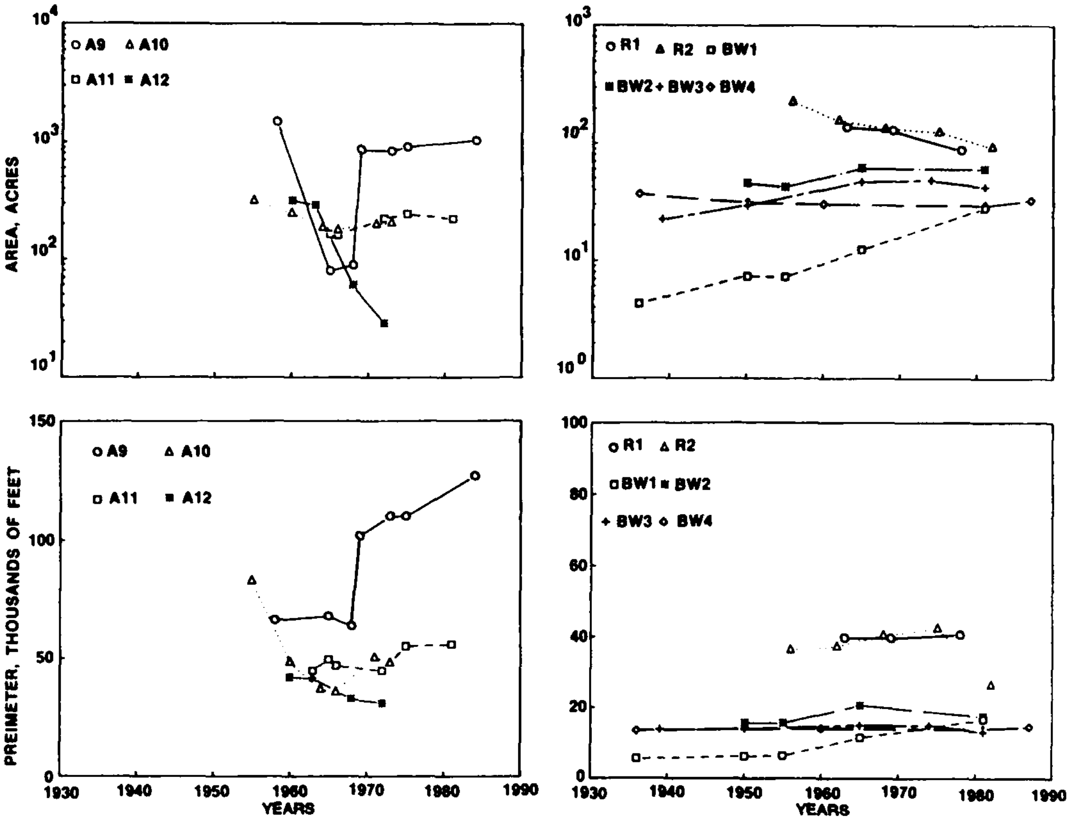


Figure 16. Tree line-enclosed area and perimeter, Arkansas, Red, and Black Warrior River sites

Lake Catherine near Columbus, MS, and Dead River, adjacent to the Dead River cutoff. These three sites are adjacent to Gainesville, Aliceville, and Columbus Pools, respectively.

72. Lubbub Creek (site T2) cutoff was formed prior to 1937. The 1937 photography shows flow from the creek into the Tombigbee River through the upper arm of the bendway, apparently due to the fact that sediment from the creek had deposited in the bendway just downstream of the creek mouth. Accordingly, the 1937 data are representative of conditions at the end of the blockage phase. The 1965 coverage shows flow from the creek reaching the Tombigbee River through the lower limb of the bendway. The area enclosed by the tree line declined by about 60 percent between 1937 and 1949, but then remained fairly constant until Gainesville Pool was raised in 1979. Enclosed area increased from only 42.8 acres to 185.1 acres due to impoundment of

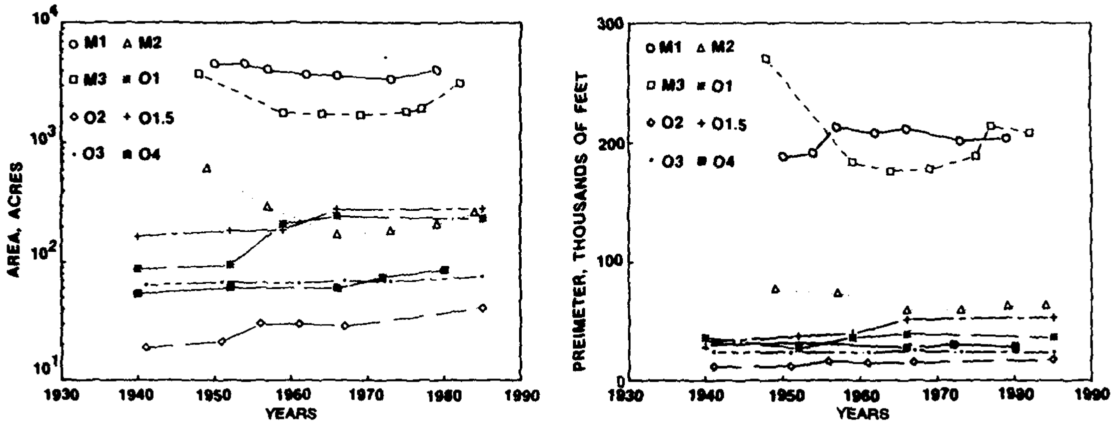


Figure 17. Tree line-enclosed area and perimeter, Mississippi and Ouachita River sites

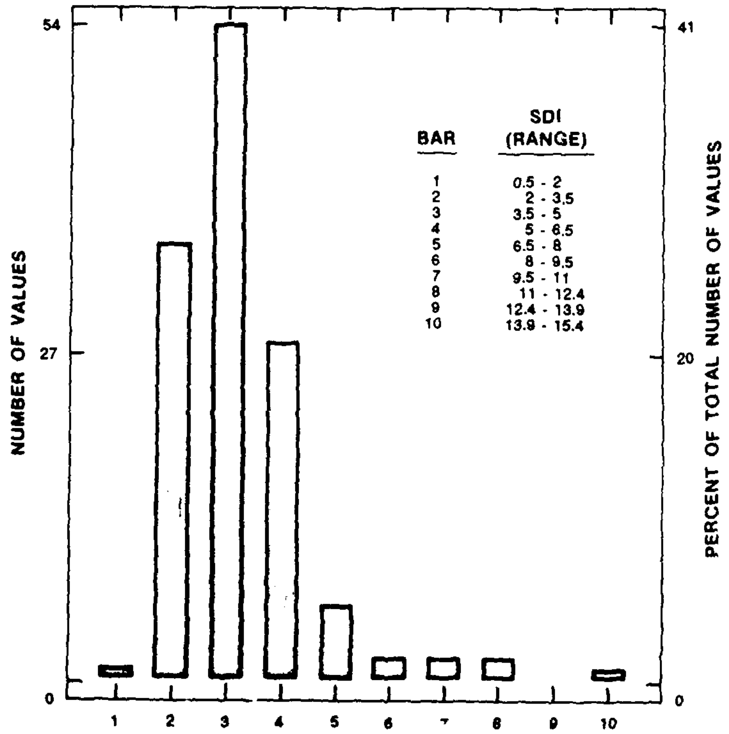


Figure 18. Frequency histogram, Shoreline Development Index

Gainesville Pool. The tree line perimeter remains nearly constant over the preimpoundment period of record.

73. Lake Catherine (site T3) was formed sometime in the 19th century by construction of a small dam across the lower end of an old meander scar just south of Columbus, MS. A survey dated 1823 shows only a small pond located at the northern end of the present lake. The area enclosed by the tree line varied less than 10 percent between 1937 and 1986. Evidently, the elevation of the lake has prevented flood flows from the Tombigbee River from reaching it except on rare occasions. The stage of record at the nearby Columbus gage is about 171 ft msl (19 March 1973), which would have reached the lake.

74. Dead River is a very narrow slough located just east of the lower limb of James Creek bendway on the Tombigbee River. The eastern limb of Dead River is connected to the Tombigbee by a small channel. The area enclosed by the tree line increased between 1958 and 1969 due to construction of a small dam across the western end of the slough. Percentage variation of measured areas is greater for this site, probably because the site was so small and narrow.

75. Overall, the morphology of the four Tombigbee River sites was stable during the 49-year period of observation. Only Lubbub Creek cutoff showed significant decrease in enclosed area, and this was during the last part of the blockage phase.

Arkansas and Verdigris Rivers

76. Seven sites along the McClellan-Kerr Waterway portion of the Arkansas River were selected for study: the four man-made bendways studied earlier (sites A9, A10, A11, and A12) (Shields 1987); two additional man-made bendways (sites A6 and A8); and one natural oxbow (site A1), located just south of site A9. Two sites were also selected along the Verdigris River, which is the upstream portion of the McClellan-Kerr Waterway. Site A3 is a very narrow, old natural oxbow, and site A13 is a man-made bendway with a blockage embankment at the upstream end.

77. The area enclosed by the tree line around the Arkansas River natural oxbow (site A1) declined about 40 percent between 1940 and 1965, but increased following closure of Lock and Dam No. 65 in December 1968. All of the man-made cutoffs showed decreases in tree line-enclosed areas during the period prior to impoundment of the navigation pools. Bendway morphology was more stable during the 15 to 20 years following impoundment of navigation

pools. All of the bendways have increased in area except site A8, which has decreased about 40 percent. The rate of change in site A8 may be related to the location of the bendway relative to the main channel. In plan, the bendway looks more like an old side channel than an old meander loop, and the upstream entrance makes a very gradual angle with the main channel. The entire length of the bendway is very near the main channel relative to the other sites. The largest increase in area was observed at site A11, McClean Bend. The area measured from photographs taken just after impoundment was depressed somewhat by the occurrence of partially submerged trees. Evidently the bed of the old bend was not cleared prior to pool raising. These trees died and decayed and do not appear on subsequent photos, thus leading to larger enclosed areas.

Red River

78. Two man-made bendways were selected for study from the reach of the Red River just upstream of Alexandria, LA. Site R1 was cut off between 1956 and 1963, while Site R2 was cut off in the late 1940s. Neither site was influenced by dam construction during the period of interest. Tree line-enclosed area decreased rapidly at both of these sites. Site R1 was rather unusual in that the downstream entrance was blocked in the 1963 photographs, but the upstream entrance was still partially open to the main channel.

Ouachita River

79. Five sites along the Ouachita River in Louisiana between Jonesville and just upstream of Monroe were selected for study. All were cut off prior to the earliest available photo coverage (1930s). The reach of the Ouachita under consideration was initially canalized in the early 1900s by a series of six locks and dams to provide minimum navigable depths of 6.5 ft. In 1972, new locks and dams in the study reach at Jonesville and Columbia were completed to increase the project depth to 9 ft. Three of the study sites (O1, O1.5, and O2) were blocked at both ends and had no surface water connection with the main channel during the period of interest. However, examination of the photos revealed that all three of these lakes were raised by construction of small dams across one of their ends during the period of interest. Tree line-enclosed areas increased gradually after construction of the small dams as the flooded trees died and decayed. Sites O3 and O4 were connected to the main channel at at least one end, and were noticeably enlarged after

navigation pools were raised in 1972. The enlargement of sites 03 and 04 was also very gradual.

Mississippi River

80. Three bendways along the Lower Mississippi River between Memphis, TN, and just downstream of Natchez, MS, were selected for study. Sites M3 and M2 were cut off in 1933, and site M1 was cut off in 1942. Photo coverage dates fell between 1948 and 1984. Tree line-enclosed areas declined at all three sites prior to the 1973 flood and increased slightly thereafter. The most recently measured areas at sites M2 and M3 were about 42 and 56 percent, respectively, of the initially measured values (1949 and 1948). In contrast, the tree line-enclosed area at site M1 in 1979 was about 88 percent of its 1950 value. One major difference between M1 and the other two sites is the length of time that was required to develop the new channel. Both M2 and M3 required 6 to 9 years of corrective dredging to enlarge and develop the cut channel. The extremely large change in channel slope that occurred when M1 was cut off caused the cut channel to develop on its own in only a few months. The ratio of bend channel length to cut channel length for sites M1, M2, and M3 was 9.89, 2.13, and 3.25, respectively.

Black Warrior River

81. Four bendways along the Black Warrior River, evidently all natural cutoffs, were selected for study. All four sites were located on the left bank of the Selden Lock and Dam pool between river miles 282 and 297. The study reach was initially canalized in 1903 by two locks and dams that provided minimum depths of 6 ft. These structures were raised to provide 9-ft depths after a 1935 authorization. The old locks and dams were replaced by Selden Lock and Dam in 1957.

82. Tree line-enclosed area at site BW1 was relatively sensitive to changes in water surface elevation because it was the shallow remnant of an old natural oxbow. When old Lock No. 8, located just downstream of BW1, was raised, it resulted in a 70-percent increase in tree line-enclosed area at BW1 between 1936 and 1950. Both BW1 and BW2 showed large increases (400 and 40 percent, respectively) in tree line-enclosed area after closure of Selden Lock and Dam. The enlargement of BW1 is due to the death and decay of trees growing in the upper end of the old meander scar. Site BW2 was cut off between 1950 and 1955. Closure of Selden Lock resulted in reestablishment of the connection with BW2. Blockage was reestablished by 1982. Gradual die-off

of flooded timber around the perimeter of BW2 evidently caused the observed increase in area.

83. Based on comparison of the 1939 and 1965 measurements, tree line-enclosed area at site BW3 increased more than 100 percent following closure of Selden Lock and Dam, but varied less than 11 percent between 1965 and 1981. Tree line-enclosed area at BW4 was relatively stable over the entire period of record, varying less than 11 percent between 1936 and 1987. In summary, BW1 generally increased in size after impoundment due to timber die-off, while the other sites were stable or reached stable levels within a few years after the 1957 impoundment.

Factors Controlling Infilling Rates

84. To facilitate comparison of results from different sites, data from the aerial photo measurements were expressed in dimensionless form as shown in Table 12. Dimensionless areas and perimeters were obtained by dividing the tree line-enclosed area, A, and tree line perimeter, P, by their initial value, A_i' and P_i', with initial values defined as either the earliest values or, for sites affected by impoundment, the values obtained from the earliest photo coverage after impoundment. Eleven of the 13 impounded sites had preimpoundment periods of record sufficiently long to permit calculation of two time series (for example, T4 in Table 12).

85. The dimensionless area and elapsed time values shown in Table 12 were used to generate time-series plots, and data were organized into groups based on the slopes of the curves in these plots. For each group, simple linear regression was used to determine if the rates of change of dimensionless tree line-enclosed area were statistically significant. Results are presented in Table 13 and Figure 19. Some of the plots in Figure 19 (T2; A9, A11, A12; A1, A3, A10; and M2, M3) display patterns more akin to log-decay relations than linear. However, for the sake of uniformity, linear regression was used for all sites. The purpose of these regressions was not to generate predictive models but to test the average rates of areal change for significance.

86. In general, the areas for sites on free-flowing rivers (the Arkansas River prior to impoundment, the Red River, and the Mississippi River) became smaller with the passage of time (1 to 9 percent annually), while areas

Table 12

Infilling Phase Data in Dimensionless Form

Site*	Date	Impounded	Elapsed Time years	Area acres	Perimeter ft	A/A_i'	P/P_i'
T2	02 Dec 37	No	0.0	91.0	3.47 E+04	1.000	1.000
T2	15 Nov 49	No	12.0	36.2	3.31 E+04	0.398	0.955
T2	19 Dec 59	No	22.1	37.3	3.21 E+04	0.410	0.926
T2	01 Dec 65	No	28.0	37.9	3.68 E+04	0.417	1.061
T3	30 Sep 37	Yes	0.0	40.9	1.25 E+04	1.000	1.000
T3	05 Feb 52	Yes	14.4	44.7	1.38 E+04	1.093	1.106
T3	16 Nov 63	Yes	26.1	38.7	1.32 E+04	0.946	1.056
T3	16 Oct 86	Yes	49.1	38.0	1.29 E+04	0.929	1.037
T4	27 Sep 37	No	0.0	9.9	1.34 E+04	1.000	1.000
T4	05 Feb 52	No	14.4	13.6	1.61 E+04	1.368	1.201
T4	11 Nov 58	No	21.1	12.7	1.44 E+04	1.278	1.074
T4	22 Mar 69	Yes	0.0	14.0	1.42 E+04	1.000	1.000
T4	15 Sep 72	Yes	3.5	15.5	1.78 E+04	1.108	1.253
T4	16 Oct 86	Yes	17.6	15.9	1.68 E+04	1.137	1.186
A1	20 Aug 40	No	0.0	173.6	3.37 E+04	1.000	1.000
A1	05 Nov 49	No	9.2	162.3	3.43 E+04	0.935	1.017
A1	04 Nov 55	No	15.2	99.3	2.64 E+04	0.572	0.783
A1	08 Oct 65	No	25.2	100.2	2.81 E+04	0.577	0.833
A1	19 Jan 73	Yes	0.0	147.1	3.03 E+04	1.000	1.000
A1	04 Apr 75	Yes	2.2	133.7	3.30 E+04	0.909	1.090
A1	07 Feb 83	Yes	10.1	166.8	3.27 E+04	1.134	1.080
A3	12 Jul 58	No	0.0	29.5	6.18 E+04	1.000	1.000
A3	08 Oct 64	No	6.2	26.3	4.36 E+04	0.892	0.706
A3	22 Mar 72	Yes	0.0	25.8	3.94 E+04	1.000	1.000
A3	20 Jul 84	Yes	12.3	32.8	5.23 E+04	1.271	1.327
A6	14 Mar 72	Yes	0.0	739.9	8.79 E+04	1.000	1.000
A6	09 Dec 77	Yes	5.7	824.8	7.38 E+04	1.115	0.840
A6	09 Feb 87	Yes	14.9	859.6	6.32 E+04	1.162	0.719
A8	13 Feb 62	Yes	0.0	262.6	5.07 E+04	1.000	1.000
A8	08 Feb 87	Yes	25.0	155.1	5.56 E+04	0.591	1.095
A9	12 Nov 58	No	0.0	1,507.0	6.63 E+04	1.000	1.000
A9	08 Oct 65	No	6.9	79.2	6.77 E+04	0.053	1.020
A9	19 Sep 68	No	9.9	89.4	6.39 E+04	0.059	0.963
A9	19 Mar 69	Yes	0.0	871.0	1.02 E+05	1.000	1.000

(Continued)

* Site locations and descriptions are given in Figure 3 and Table 3.

(Sheet 1 of 4)

Table 12 (Continued)

Site	Date	Impounded	Elapsed Time years	Area acres	Perimeter ft	A/A'_i	P/P'_i
A9	19 Jan 73	Yes	3.8	842.0	1.10 E+05	0.967	1.084
A9	21 Oct 75	Yes	6.6	919.8	1.10 E+05	1.056	1.085
A9	08 Jan 84	Yes	14.8	1051.5	1.27 E+05	1.207	1.246
A10	08 Oct 55	No	0.0	315.9	8.29 E+04	1.000	1.000
A10	01 Dec 60	No	5.2	246.6	4.84 E+04	0.781	0.584
A10	03 Oct 64	No	9.0	187.0	3.68 E+04	0.592	0.444
A10	12 Oct 66	No	11.0	178.0	3.55 E+04	0.563	0.428
A10	26 Oct 71	Yes	0.0	200.0	5.02 E+04	1.000	1.000
A10	29 Jan 73	Yes	1.3	205.4	4.81 E+04	1.027	0.958
A11	13 Jun 63	No	0.0	396.0	4.46 E+04	1.000	1.000
A11	20 Feb 65	No	1.7	163.8	4.94 E+04	0.414	1.106
A11	25 Oct 66	Yes	0.0	160.0	4.69 E+04	1.000	1.000
A11	17 Dec 72	Yes	6.2	223.0	4.46 E+04	1.394	0.950
A11	13 Nov 75	Yes	9.1	244.0	5.51 E+04	1.525	1.176
A11	23 Dec 81	Yes	15.2	223.2	5.58 E+04	1.395	1.190
A12	10 Nov 60	No	0.0	316.0	4.18 E+04	1.000	1.000
A12	29 May 63	No	2.5	291.0	4.17 E+04	0.921	0.997
A12	10 Sep 68	No	0.0	60.8	3.28 E+04	0.192	0.786
A12	27 Dec 72	No	4.3	29.0	3.08 E+04	0.092	0.737
A13	22 Mar 72	Yes	0.0	24.0	1.11 E+04	1.000	1.000
A13	20 Jul 84	Yes	12.3	25.5	1.12 E+04	1.063	1.015
R1	07 Nov 63	No	0.0	139.7	3.97 E+04	1.000	1.000
R1	29 Nov 69	No	6.1	129.3	3.96 E+04	0.926	0.996
R1	09 Nov 78	No	15.0	88.3	4.07 E+04	0.632	1.024
R2	29 Dec 56	No	0.0	228.1	3.62 E+04	1.000	1.000
R2	26 Mar 62	No	5.2	158.9	3.72 E+04	0.697	1.029
R2	15 Oct 68	No	11.8	136.0	4.05 E+04	0.596	1.119
R2	27 Jan 75	No	18.1	125.1	4.22 E+04	0.548	1.166
R2	22 Feb 82	No	25.2	92.6	2.62 E+04	0.406	0.725
O1	18 Sep 40	No	0.0	88.0	2.44 E+04	1.000	1.000
O1	04 Sep 52	No	12.0	96.3	2.70 E+04	1.094	1.107
O1	19 Oct 59	Yes	0.0	212.2	3.62 E+04	1.000	1.000
O1	28 Nov 66	Yes	7.1	245.4	3.91 E+04	1.156	1.079
O1	27 Sep 85	Yes	26.0	234.3	3.69 E+04	1.104	1.019
O1.5	18 Sep 40	No	0.0	164.8	3.30 E+04	1.000	1.000
O1.5	04 Sep 52	No	12.0	184.4	3.78 E+04	1.119	1.144
O1.5	23 Oct 59	No	19.1	189.4	3.99 E+04	1.149	1.210

(Continued)

(Sheet 2 of 4)

Table 12 (Continued)

Site	Date	Impounded	Elapsed Time years	Area acres	Perimeter ft	A/A'_i	P/P'_i
01.5	28 Nov 66	Yes	0.0	278.1	5.18 E+04	1.000	1.000
01.5	27 Sep 85	Yes	18.8	282.1	5.35 E+04	1.014	1.033
02	11 Oct 41	No	0.0	18.8	1.17 E+04	1.000	1.000
02	16 Jan 51	No	9.3	21.5	1.21 E+04	1.144	1.029
02	18 May 56	Yes	0.0	30.2	1.60 E+04	1.000	1.000
02	09 Jan 61	Yes	4.6	30.2	1.53 E+04	1.000	0.956
02	18 Nov 67	Yes	11.5	28.8	1.55 E+04	0.954	0.968
02	08 Feb 85	Yes	28.7	40.7	1.79 E+04	1.348	1.117
03	11 Nov 41	No	0.0	63.6	2.42 E+04	1.000	1.000
03	16 Jan 51	No	9.2	68.8	2.39 E+04	1.082	0.988
03	09 Jan 61	No	19.2	66.9	2.39 E+04	1.052	0.989
03	06 Nov 67	No	26.0	69.9	2.55 E+04	1.099	1.053
03	10 Feb 73	Yes	0.0	68.5	2.46 E+04	1.000	1.000
03	12 Feb 85	Yes	12.0	75.6	2.44 E+04	1.104	0.991
04	18 Sep 40	No	0.0	54.2	3.08 E+04	1.000	1.000
04	04 Sep 52	No	12.0	61.0	3.19 E+04	1.125	1.036
04	28 Nov 66	No	26.2	60.7	2.84 E+04	1.120	0.922
04	19 Feb 72	Yes	0.0	74.6	3.06 E+04	1.000	1.000
04	24 Jan 80	Yes	7.9	86.0	2.86 E+04	1.153	0.936
BW1	25 Apr 59	Yes	0.0	7.2	6.50 E+03	1.000	1.000
BW1	23 Oct 65	Yes	6.5	12.4	1.14 E+04	1.722	1.760
BW1	17 Nov 81	Yes	22.6	27.9	1.66 E+04	3.875	2.555
BW2	25 Apr 59	Yes	0.0	42.4	1.57 E+04	1.000	1.000
BW2	23 Oct 65	Yes	6.5	62.2	2.06 E+04	1.467	1.314
BW2	17 Nov 81	Yes	22.6	60.4	1.76 E+04	1.425	1.125
BW3	17 Oct 65	Yes	0.0	47.2	1.49 E+04	1.000	1.000
BW3	12 May 74	Yes	8.6	48.7	1.49 E+04	1.032	1.000
BW3	17 Nov 81	Yes	16.1	42.4	1.31 E+04	0.898	0.877
BW4	21 Mar 60	Yes	0.0	30.3	1.42 E+04	1.000	1.000
BW4	17 Nov 81	Yes	21.7	29.4	1.40 E+04	0.970	0.991
BW4	20 Sep 87	Yes	27.5	32.4	1.46 E+04	1.069	1.029
M1	07 Apr 50	No	0.0	4,559.4	1.88 E+05	1.000	1.000
M1	26 Feb 54	No	3.9	4,527.4	1.91 E+05	0.993	1.020
M1	06 Oct 57	No	7.5	4,011.8	2.13 E+05	0.880	1.137
M1	14 Nov 62	No	12.6	3,723.2	2.08 E+05	0.817	1.108

(Continued)

(Sheet 3 of 4)

Table 12 (Concluded)

Site	Date	Impounded	Elapsed Time years	Area acres	Perimeter ft	A/A_i'	P/P_i'
M1	26 Oct 66	No	16.6	3,573.8	2.12 E+05	0.784	1.130
M1	21 Nov 73	No	23.6	3,397.0	2.02 E+05	0.745	1.079
M1	25 Oct 79	No	29.6	4,025.0	2.04 E+05	0.883	1.088
M2	16 Nov 49	No	0.0	612.0	7.69 E+04	1.000	1.000
M2	17 Feb 57	No	7.3	290.0	7.31 E+04	0.474	0.952
M2	03 Nov 66	No	17.0	170.0	5.96 E+04	0.278	0.775
M2	01 Nov 73	No	24.0	183.0	5.94 E+04	0.299	0.773
M2	26 Oct 79	No	30.0	208.0	6.28 E+04	0.340	0.817
M2	29 Jan 84	No	34.2	257.0	6.36 E+04	0.420	0.828
M3	15 Jun 48	No	0.0	3,748.0	2.70 E+05	1.000	1.000
M3	18 Oct 59	No	11.3	1,774.0	1.84 E+05	0.473	0.680
M3	07 Oct 64	No	16.3	1,732.0	1.76 E+05	0.462	0.652
M3	15 Nov 69	No	21.4	1,708.0	1.78 E+05	0.456	0.657
M3	31 Oct 75	No	27.4	1,816.0	1.89 E+05	0.485	0.700
M3	07 Feb 77	No	28.7	1,952.0	2.14 E+05	0.521	0.791
M3	07 Mar 82	No	33.7	2,098.0	2.09 E+05	0.560	0.773

(Sheet 4 of 4)

Table 13

Average Annual Rates of Change for Tree Line-Enclosed Area

No.	River	Sites	Period	Average Rate, %	r^2	t-Probability
1	Tombigbee	T2	Preimpoundment	-2.0	0.68	0.1726
2	Tombigbee	T3	All	-0.2	0.38	0.3811
3	Arkansas	A9, A11, A12	Preimpoundment	-8.5	0.80	0.0011*
4	Arkansas	A1, A3, A10	Preimpoundment	-2.0	0.64	0.0058*
5	Arkansas	A1, A6, A9, A10, A13	Postimpoundment	1.4	0.68	<0.0001*
6	Red	R1, R2	All	-2.3	0.87	0.0007*
7	Ouachita	O1, O1.5, O2, O3, O4	All	0.6	0.44	0.0002*
8	Mississippi	M1	All	-0.6	0.46	0.0937
9	Mississippi	M2, M3	All	-1.3	0.42	<0.0001*
10	Black Warrior	BW3, BW4	Postimpoundment	0.0	0.00	0.9352
11	Nos. 1, 4 and 6			-2.2	0.76	<0.0001*

Note: The t-probability is a measure of the significance of the regression coefficient used to determine average annual rate. It is the fractional probability that the population regression coefficient is zero and that there is no relationship between area and time. Asterisks indicate average rates significant at the 95-percent confidence level.

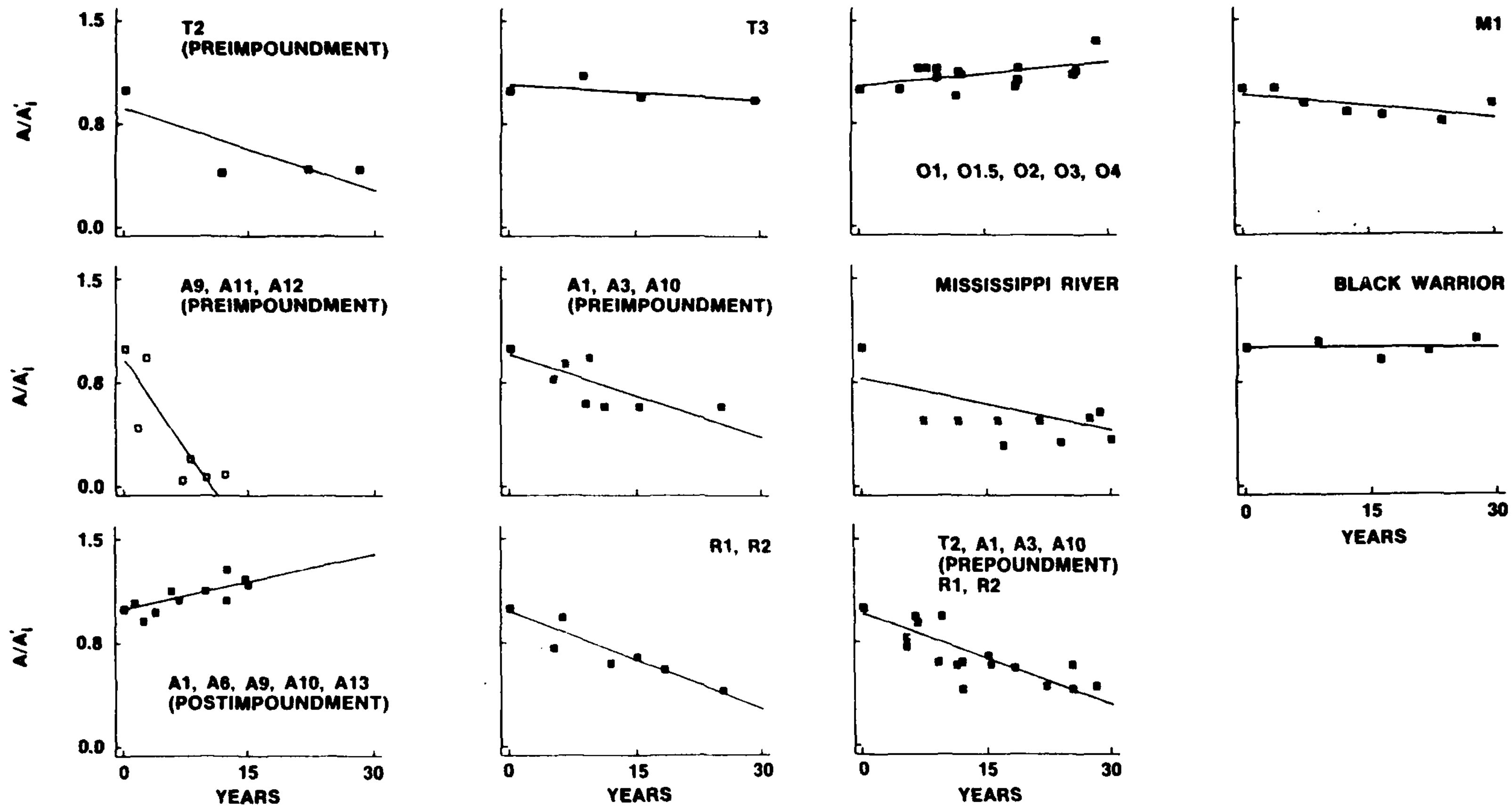


Figure 19. Linear regression results, dimensionless tree line-enclosed area versus elapsed time

for sites along run-of-river navigation impoundments (the Arkansas River after impoundment, the Ouachita River, and the Black Warrior River) either became slightly larger during the period of observation or changed at rates too slow for detection (regressions were statistically insignificant). The three sites on the Tombigbee River displayed differing responses: area for T2 (Lubbub Creek) became smaller prior to impoundment, area for T3 was stable over the entire period of interest, and tree line-enclosed area at T4 first increased and then decreased slightly.

87. To examine the relative importance of some of the factors controlling infilling rates, simple linear regression was used to compute an average rate of change of tree line-enclosed area at each site. Data reflecting die-off of flooded timber were omitted from this phase of the analysis. An exception was made in the case of the Ouachita River data because inclusion of data points reflecting timber die-off did not materially influence the rate of change. The resultant rates, in units of percent area per year, are shown in Table 14 along with dimensionless forms of three of the major controlling variables. The average suspended-sediment concentrations shown in Table 14 are simply rough estimates that give a general indication of the relative magnitudes of the sediment loads of the study reaches. Sources for the sediment data are noted in the footnote to the table. Length ratios (ratio of bend length to cut channel length) were available from literature for the man-made bendways. Length ratios were measured from aerial photographs for recent natural cutoffs but were impossible to determine for older sites such as T3. The drainage area ratios were obtained by measuring local drainage area for each site from 1:24,000 USGS quad sheets and dividing by the maximum observed tree line-enclosed area for that site. Drainage areas for sites A9 and A12 were indeterminate because of complex connections to other major drainage areas shown on the quad sheets.

88. Correlation analysis and scatter plots were used to explore the relationship between the average annual rates of change and the three controlling variables shown in Table 14. The variation in average suspended-sediment concentration explained 70 percent of the variance in average annual change in area, and the length ratio explained 2 percent of the residual variance. If sites A3 and A10 were omitted from the data set, average suspended sediment concentration explains 90 percent of the variance in average annual change in area.

Table 14

Average Annual Rates of Change of Tree Line-Enclosed Area and Controlling Factors

River	Site No.	Site Name	Average Rate of Change, %	Average Suspended Sediment Concentration, ppm*	Length Ratio	Drainage Area/ Maximum Tree Line Area
Tombigbee	T2	Lubbub Creek	-2.0	181	15.2	79,710.8
Tombigbee	T3	Lake Catherine	-0.2	161		7.2
Arkansas	A1	Old River Lake	-1.9	400		6.0
Verdigris	A3	Old River Channel	-17.4	2,700	6.5	1,766.2
Arkansas	A8	Hensley Bar	-2.4	400	1.5	12.4
Arkansas	A9	Brodie	-10.3	2,700	3.5	
Arkansas	A10	Morrilton	-4.1	2,700	8.4	33.0
Arkansas	A12	Trustee	-8.4	2,700	1.8	
Red	R1	Dixon Bend	-2.5	1,060	11.2	18.1
Red	R2	McNeeley	-2.1	1,060	9.6	2.5
Ouachita	03	Horseshoe Lake	0.3	43		52.1
Ouachita	04	Rawson Creek	0.5	43		575.1
Mississippi	M1	Hardin	-0.6	290	9.9	5.8
Mississippi	M2	Worthington	-5.5	290	2.1	14.5
Mississippi	M3	Glasscock	-1.1	290	4.0	6.0
Black Warrior	BW3	Kings Cutoff	-0.6	29	18.0	7.2
Black Warrior	BW4	Keaton Lake	0.2	29	12.9	13.3

* Sources of sediment data by site number: T2 - mean annual sediment input from Lubbub Creek to Gainesville Lake and mean annual Lubbub Creek discharge given in USAED, Mobile (1976); T3 - preproject Tombigbee River conditions at Columbus Dam site, USAED, Mobile (1978); A1 and A8 - Petersen (1986); A3, A9, A10, A12 - ASCE Task Committee (1965); R1 and R2 - Yu and Wolman (1986); O3 and O4 - USAED, St. Louis (1987); M1, M2, and M3 - Keown, Dardeau, and Causey (1981); and BW3 and BW4 - data furnished by the Alabama District of the US Geological Survey.

PART V: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Conclusions

89. Results of annual hydrographic surveys of 14 cutoff bendways located in the River Section of the TTW collected between 1977 and 1987 were analyzed. Based on this analysis, the volume of deposition below normal pool elevation in the 30 bendways located downstream of Aberdeen Lock and Dam was estimated to be 14.4 million cubic yards. However, with the exception of the upper portion of Columbus Lake and Big Creek Bend, the deposition did not affect the aquatic surface area at normal pool elevation. On the other hand, reduction in mean depth was significant. Mean depth for the 14 monitored bendways decreased 3 ft. The average rate of depth reduction was -0.6 ft per year. Deposition rates slowed between 1985 and 1987 due to extremely low discharges and effects of existing sediment deposits in the upstream bendway entrances.

90. Little quantitative information is available regarding deposition in the eight bendways located in Aberdeen Lake. Visual inspection and examination of plots of the available hydrographic survey data indicate that those bendways are undergoing deposition similar to the bendways in the downstream impoundments.

91. Neither the volume nor the pattern of deposition of sediment in the bendways appears to be related to the location of the bendways in the reservoir pools. However, bendways located lower in the pools (closer to the upstream side of the dams) have much more volume below normal pool elevation to store sediments. Although deposition rates at the lower and midpool bendways are just as great as for the upper pool sites and deposition volumes are greater at these locations (because the bendways are larger), problems at these locations are not yet visible.

92. Sediments deposited in the bendways are derived either from the main channel or from the local drainage area tributary to each bendway. The former source is much more important during higher flows. The contribution of sediment from the main channel is greatly reduced when the upstream bendway entrance is blocked to top-bank elevation either naturally or by man. For this reason, blockage of all of the bendways was recommended earlier (Shields 1987), with blocks modified to include a small boat channel placed at bendways longer than 1 mile. Three bendways were blocked in the summer of 1985, and

nine were blocked in the summer of 1987 One of the 1987 blocks is a modified block. Until woody vegetation similar to that found on the adjacent floodplain is established on the blockage structures, they will be extremely vulnerable to erosion whenever stages approach or exceed their crest elevations. Bendways that are not blocked will continue to lose volume rapidly due to deposition. Bendways that receive significant amounts of sediment from local drainage (such as Dead River, Lubbub Creek, and Big Creek Bend) will continue to experience substantial deposition even after blockage. No feasible solutions to this problem are known.

93. One alternative for prolonging the lifetime of aquatic habitat at bendways that have experienced significant deposition and that are located in the upper portion of a navigation pool (such as Big Creek Bend) is to construct small dams across the upstream and downstream entrances and permanently raise the water level in the bendway. Disadvantages include the cost of the dam and the isolation of the bendway from the main channel. Also, sediments from tributaries and the local drainage area will continue to deposit.

94. To determine the long-term outlook for the bendways after they are blocked, a data set was compiled of historical observations of the perimeter and enclosed area of tree lines around 26 floodplain water bodies. All of these water bodies were either man-made bendways in the infilling phase or natural oxbow lakes along alluvial rivers in the southeastern United States. The data were based on aerial photography, with roughly 50 years of record available. However, only about 30 years of observation were available for most of the sites because water levels were permanently raised during the period of observation by construction of either navigation dams or small embankments across one end of the oxbow or bendway.

95. Tree line-enclosed areas declined 1 to 9 percent per year for sites located along free-flowing rivers with average suspended sediment concentrations of 200 ppm or greater. Sites along canalized rivers had rates of change too low for detection with the techniques employed. The rate of change of area was found to be closely related to the average main channel suspended-sediment concentration and to the ratio of bend length to cut channel length. Evidently, bendways and oxbows with greater length ratios tend to fill more slowly because (a) they tend to have shorter radii before they are cut off and thus greater depths (Wolff 1978) and (b) they extend further from the main

river channel, thus forcing floodwaters to traverse generally greater distances to reach the old channel (Gagliano and Howard 1984).

96. Tree line perimeters and shoreline development indices tended to be rather stable with time relative to tree line-enclosed area. Shorelines became more complex as lakes grew smaller, underscoring the persistence of the habitat values of these areas. Shoreline development indices were generally high, averaging 4.7 for the entire data set, more than twice the mean value of 2.2 reported by Buglewiscz et al. (1988) for 25 Lower Mississippi River main stem levee borrow pits.

97. Three of the 26 study sites examined in this study were located along the Tombigbee River. The only one that had a significant rate of area decline (Lubbub Creek) received sediment from a tributary with a large drainage area. Based on observations of the other systems and the estimated postproject sediment load of the Tombigbee River, TTW bendways that receive little sediment from local drainage should decline in size very slowly (less than 1 percent annually) after blockage. Bendways with higher length ratios generally decline most slowly.

Recommendations

98. Existing bendway blockage structures should be protected from erosion either by placement of stone protection or rapid development of a vigorous cover of woody vegetation.

99. Existing data from man-made bendways and similar water bodies along the TTW and similar systems should be examined to study relationships between bendway morphology and biology.

100. Serious consideration should be given to constructing blockage structures at the upstream entrances of the 25 bendways that still contain significant aquatic area and are not presently blocked. Priority should be given to blocking bendways in Aberdeen Lake and Columbus Bend. The bendways in Aberdeen Lake are the most recently constructed on the TTW, and thus more potential remains for arresting blockage-phase sedimentation. Furthermore, the sediment load into Aberdeen is relatively high because the upstream drainage area is uncontrolled. Columbus Bend is important because of its size and location. Projections made above indicate it may experience rapid deposition during future flood events.

101. Delay of blockage construction at bendways located deep in the reservoir pools will have little noticeable effect on aquatic area for a long time to come. However, the longer blockage is delayed, less bendway volume will be available to store sediment during the infilling phase. The volume of sediment deposits makes restoration of filled bendways economically infeasible. Overall terrestrialization of the system will occur sooner if blockage is delayed.

REFERENCES

American Society of Civil Engineers Task Committee on Channel Stabilization Works. 1965. "Channel Stabilization of Alluvial Rivers - Progress Report," Journal of the Waterways and Harbors Division, American Society of Civil Engineers, Vol 91, No. WW1, pp 7-37.

Annandale, G. W. 1987. Reservoir Sedimentation, Elsevier, Amsterdam, The Netherlands.

Buglewiscz, E. G., et al. 1988. "A Physical Description of Main Stem Levee Borrow Pits Along the Lower Mississippi River," Lower Mississippi River Environmental Program, Report 2, US Army Corps of Engineers, Mississippi River Commission, Vicksburg, MS.

Ebert and Associates. "Reservoir Bank Erosion and Cultural Resources: Experiments in Mapping and Predicting the Erosion of Archeological Sediments at Reservoirs Along the Middle Missouri River with Sequential Historical Aerial Photographs," Technical Report (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Gagliano, Sherwood M., and Howard, Perry C. 1984. "The Neck Cutoff Oxbow Lake Cycle Along the Lower Mississippi," River Meandering, Proceedings of the Conference River 83, American Society of Civil Engineers, New York, pp 147-158.

Headquarters, US Army Corps of Engineers. 1987. "Reservoir Water Quality Analysis," Engineer Manual 1110-2-1201, Washington, DC.

Keown, Malcolm, Dardeau, Elba A., and Causey, Etta M. 1981. "Characterization of the Suspended-Sediment Regime and Bed-Material Gradation of the Mississippi River Basin," LMVD Potamology Program (P-1), Report 1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Petersen, Margaret S. 1986. River Engineering, Prentiss-Hall, Englewood Cliffs, NJ.

Shields, F. D. 1987. "Management of Environmental Resources Associated with Cutoff Bends Along the Tennessee-Tombigbee Waterway," Miscellaneous Paper EL-87-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stevens, J., and Barcikowski, R. S. 1980. Applied Multivariate Statistics for the Social Sciences, University Press of America, Chap. 3.

US Army Engineer District, Mobile. 1976. Gainesville Lock and Dam Sedimentation Program," Design Memorandum No. 19, Mobile, AL.

__________. 1981. "Tennessee-Tombigbee Waterway Bendway Tas Force, Phase I Report," Mobile, AL.

__________. 1978. "Columbus Lock and Dam, Sedimentation Program," Design Memorandum No. 18, Mobile, AL.

__________. 1984. "Supplement to the Project Design Memorandum, Bendway Management Study, Tennessee-Tombigbee Waterway, Alabama and Mississippi," Mobile, AL.

US Army Engineer District, St. Louis. 1987. "Ouachita and Black Rivers, Red River Basin, Arkansas and Louisiana, Nine-Foot Navigation Project, Calion, Felsenthal, and Columbia Pools; Vol 1, Text and Computation," Design Memorandum No. 90, St. Louis, MO.

US Fish and Wildlife Service. 1987. "A Study of Cutoff Bendways on the Tennessee-Tombigbee Waterway, 1986 Annual Report," submitted to US Army Engineer District, Mobile, AL, by USFWS, Daphne, AL.

__________. 1988. "A Study of Cutoff Bendways on the Tennessee-Tombigbee Waterway, 1987 Annual Report," submitted to US Army Engineer District, Mobile, Mobile, AL, by USFWS, Daphne, AL.

Wolff, Darrel E. 1978. "Engineering Geology of Missouri, River Oxbow Lakes," M.S. thesis, Iowa State University, Ames, Iowa.

Yu, Bofu, and Wolman, M. Gordon. 1986. "Bank Erosion and Related Washload Transport on the Lower Red River, Louisiana," Proceedings of the Third International Symposium on River Sedimentation, Vol III, University of Mississippi, Oxford, MS.

APPENDIX A: DATA TABLES

Table A1

Summary of Hydrographic Survey Data, Tombigbee River

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Rattlesnake Bend, Demopolis Pool, Pool = 73.00 Bank = 85.40													
101001	RB1	235.9	*	c	*	c	c		c	c	c	*	a
101002	RB2	235.7	c	c	c	*	c		*	*	*	*	*
101003	RB3	235.5	c	c	c	c	*		c	c	c	*	*
101004	RB4	235.2	*	c	*	c	*		c	c	c	*	*
101005	RB5	234.7	c	c	c	*	c		*		*	*	*
101006	RB6	233.8	*	c		c			c	c	c	*	*
101007	RB7	233.0	*	c	c	c	c		c		b,c	*	*
101008	RB8	232.5	*	c		c				c	c	*	*
101009	RB9	231.4	*	c	*	c	c		c		c	*	*
101010	RB10	230.1	*	c		*			*	*	c	*	*
101011	RB11	229.1	*	c	*	*	*		*		c	*	*
101012	RB12	227.9	*	c		c			*	*	*	*	*
101013	RB13	227.4	c	c	c	c	*		c		c	*	*
101014	RB14	226.4	*	c		c			c	a	c	*	*
101015	RB15	226.2	*	c	*	c	*		c	a	c	*	a
Rattlesnake Cut, Demopolis Pool, Pool = 73.00 Bank = 85.4													
101103	12CD	223.3	*	c	*				c		c	*	*
101104	12CC	223.6	*	c		c			c	c	c	*	c
101105	12CB	223.9	*	c	*	c	c		c	c	c	*	*

(Continued)

Notes: a = Survey obviously in error, rejected after visual inspection of plotted data.
b = Entry error.
c = Inconsistent range length.
d = Sediment deposition above normal pool elevation for entire range.
e = Bend/cut overlay.
* = Data not edited.
Pool = Normal pool elevation in feet above mean sea level.
Bank = Top-bank elevation in feet above mean sea level.

(Sheet 1 of 8)

Table A1 (Continued)

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
		Cooks Bend, Gainesville Pool, Pool = 109.00 Bank = 115.00											
203001	CB1	293.50		*	*	*	*		*	a	c	*	*
203002	CB2	293.67		*	*	*			*		c	*	*
203003	CB3	294.01		*	*	*	*			*	*	*	*
203004	CB4	294.30		*	*	*			*	*	*	a	a
203005	CB5	294.98		*	*	*	*		*			*	*
203006	CB6	295.30		*	*	*			*		*	*	*
203007	CB7	295.68		*		c	c		c	*	*	*	*
203008	CB8	295.98		*	*	*			*		*	*	*
203009	CB9	296.21		c	*	c	c		c	a	c	*	*
203010	CB10	296.53		c	c	c	c		c	a	c	*	*
203011	CB11	296.83		*	*	*	*		*	a	*	*	*
		Cooks Cut, Gainesville Pool, Pool = 109.00 Bank = 116.00											
203104	4AC (4CC)	276.90				*	*			*	*	*	*
203105	4AD (4CD)	277.20				*	*		*		*	*	*
203106	4AE (4CE)	277.69				*	*		*	*	*	*	*
203107	4AF (4CF)	277.91				*	*		*		*	*	*
		Big Creek Bend, Gainesville Pool, Pool = 109.00 Bank = 126.00											
208001	BC	331.04	*	c	*	*	*		*	a	*	*	*
208002	BCA	330.88	*	:	*	*	c		*		*	*	d
208003	BCB	330.70	c	c	c	*	*		*		*	*	*
208004	BCC	330.56	*	c	*	*	*		*		*	*	*
208005	BCD	330.03	*	c	*	*			*	a		*	*
208006	BCE	328.97	c	c	*	*			*		*	d	*
208007	BCF	328.56	*	c	*	*			*	a	*	*	*
208008	BCG	328.33	c	c	*	*			*	a	*	*	*

(Continued)

(Sheet 2 of 8)

Table A1 (Continued)

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Big Creek Cut, Gainesville Pool, Pool = 109.00 Bank = 130.00													
208102	15AA	304.50			*	*			*	a		a	*
208103	15AB	304.67			*	*			*		*	*	*
208104	15AC	304.87			*	*			*	a	*	*	*
208105	15AD	305.08			*	*				a	*	*	*
208106	15AE	305.26			*	*			*		c	*	*
208107	15AF	305.43	*		*	*			*		*	*	*
Hairston Bend, Aliceville Pool, Pool = 136.00 Bank = 142.8													
311001	1HB	347.2					*	*	*	a	*	*	*
311002	2HB	347.4					*	*	*	a	*	*	*
311003	3HB	347.7						*	c	a	*	*	*
311004	4HB	348.2					*		*	a	*	*	*
311005	5HB	348.7					*	*	*	a	*	*	*
311006	6HB	349.5					*		b	a	b	*	*
311007	7HB	350.3					*	*	*	a	*	*	*
311008	8HB	351.0					*		a	a	*	c	c
311009	9HB	351.8					*	*	*	a	*	*	*
311010	10HB	352.1					*	*	a	a	*	c	c
311011	11HB	352.3					*	*	*	a	*	*	*
311012	12HB	352.5					*	*	*	a	*	*	*
Hairston Cut, Aliceville Pool, Pool = 136.00 Bank = 146.3													
311102	11A	318.7					*	*			*	*	*
311103	12A	319.1					*	*				*	*

(Continued)

(Sheet 3 of 8)

Table Al (Continued)

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Columbus Bend, Aliceville Pool, Pool = 136.00 Bank = 155.6													
312001	8B	362.9					c	c	c	*	*	*	a
312002	9B	363.5					*	*	*	b	*	*	*
312003	10B	364.4					*	*	*	*	*	c	c
312004	11B	365.0					*	*	*	*	*	a	*
312005	12B	365.6					c	c	c	b,c	*	*	*
312006	13B	366.0					*	*	*	*	*	*	*
Columbus Cut, Aliceville Pool, Pool = 136.00 Bank = 158.8+													
312103	23A	362.9									*,*		*
312104	24A	363.0									*,*	a	*
312105	25A	363.6									*,*	*	*
312106	26A	364.0									*,*		*
312107	27A	364.4									c,*	*	*
Stinson Creek Bend, Columbus Pool, Pool = 163.00 Bank 173.6													
416001	8A	378.2					*	e	e	a	e	e	c
416002	9A	378.7					*	*	*	a	*	*	*
416003	10A	379.4					*	*	*	a	*	*	*
416004	11A	379.9					*	*	a	a	*	*	*
Stinson Cut, Columbus Pool, Pool = 163.00 Bank = 174.9													
416101	12A	340.8						*	*	*	c	*	*

(Continued)

+ Two surveys were taken in 1985--first in February, second in May.

(Sheet 4 of 8)

Table A1 (Continued)

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Town Creek Bend, Columbus Pool, Pool = 163.00 Bank = 175.2													
417001	14A	380.6					*	*	*	*	*	a	*
417002	15A	381.2					*	*	*		*	*	*
417003	16A	381.6					*	*	*	*	*	c	*
417004	17A	382.0					*	*	*	a	*	*	*
417005	19A	382.2					*	e	e		e	e	e
Town Cut, Columbus Pool, Pool = 163.00 Bank = 175.8													
417102	13A	341.7					*	*	*		*	a	a
417103	18A	342.2						*	*	*	*	*	*
Buttahatchee River Bend, Columbus Pool, Pool = 163.00 Bank = 174.6													
419001	22A	383.3					*	*	*	*	*	*	*
419002	23A	383.9					*	*	*		*	a	*
419003	24A	384.4					*	*	*	*	*	a	*
419004	25A	384.7						*	*		c		
419005	26A	385.0						*	*		c		*
419006	27A	385.3					*	*	*	*	*	*	*
419007	28A	385.6						*	*		*		c
419008	29A	385.9					*	*	*	*	*	*	*
Buttahatchee Cut, Columbus Pool, Pool = 163.00 Bank = 176.7													
419102	21A	343.8					*	*	*		*	*	*
419103	30A	344.4						*	*		*	*	*
419104	31A	344.8						*	*		*	*	*
419105	32A	345.2						*	*	*	*	*	*

(Continued)

(Sheet 5 of 8)

Table A1 (Continued)

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Vinton Creek Bend, Columbus Pool, Pool = 163.00 Bank = 172.00													
420001	34A	386.7						*	*	a	*	*	*
420002	35A	387.4					*	*	*	*	*	*	*
420003	36A	387.8					*	*	*	*	*	a	*
Vinton Cut, Columbus Pool, Pool = 163.00 Bank = 170.7													
420102	37A	346.3						*	*		*	*	*
420103	38A	346.5						e	e		e	e	e
Denmon Creek Bend, Columbus Pool, Pool = 163.00 Bank = 173.3													
421001	39A	388.4					*	*	*	*	*	*	*
421002	40A	388.8					*	*	*	*	*	*	*
421003	41A	389.2					*	c	c	*	*	*	c
Denmon Cut, Columbus Pool, Pool = 163.00 Bank = 168.8													
421103	42A	347.0							*		b	*	*
Cane Creek Bend, Columbus Pool, Pool = 163.00 Bank = 173.7													
422001	43A	389.4					*	*	*	a	*	*	*
422002	44A	389.9					*	*	*	*	*	*	*
422003	45A	390.3					*	*	*	*	*	*	d
Cane Cut, Columbus Pool, Pool = 163.00 Bank = 170.7													
422101	42A	347.0							*		*	*	*
422102	46A	347.5						*	*			*	*

(Continued)

(Sheet 6 of 8)

Table Al (Continued)

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
McKinley Creek Bend, Columbus Pool, Pool = 163.00 Bank 175.0													
423001	48A	390.8					*	*	*	*	*	*	*
423002	49A	391.2					*	*	*			*	*
423003	50A	391.6					*	*	*	*	c	*	a
423004	51A	392.0					*	*	*	a	*	c	*
423005	52A	392.4					*	*	*	*	*	*	*
423006	53A	392.8					*	*	*		c	*	*
423007	54A	393.2					*	*	*	*	*	*	*
McKinley Cut, Columbus Pool, Pool = 163.00 Bank = 175.8													
423102	47A	348.0						*	*		c	*	a
423103	55A	348.5						*	*		*	*	*
423104	56A	349.8						*	*		*	*	*
Hickleson Lake Bend, Columbus Pool, Pool = 163.00 Bank = 178.5													
427001	61A	397.0					*	*	*	*	*	*	*
427002	62A	397.4					*	*	*	*	d		d
427003	63A	397.8					*	*	*	*	d		
427004	64A	398.2					*	*	*	*			
427005	65A	398.7					*	*	*	*	*	*	
Hickleson Cut, Columbus Pool, Pool = 163.00 Bank = 178.0													
427103	66A	351.8						*	*		*	c	*
427104	67A	352.2						*	*		*	*	*

(Continued)

(Sheet 7 of 8)

Table A1 (Concluded)

WES	Mobile District	Mile	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
		James Creek Bend, Columbus Pool, Pool = 163.00 Bank = 183.1											
429001	70A	400.3					c	c		*	*	*	*
429002	71A	400.7					*	*	*		*	*	*
429003	72A	401.2					*		*	a	*	*	*
429004	73A	401.5					*		*	*	*	*	*
429005	74A	402.0					*		*	*	*	*	*
429006	75A	402.4					*		c	*	*	a	*
429007	76A	402.7					*		*	*	*	*	a
429008	77A	403.0								d	d	d	
429009	78A	403.4							d	a	d		a
		James Creek Cut, Columbus Pool, Pool = 163.00 Bank = 184.0											
429102	69A	353.1							*		*	*	*
429103	79A	353.7							*	*	*	a	*
429104	80A	354.4							*		*	*	c
429105	81A	354.9							*		c	a	a
429106	82A	355.3							*	*	*	a	*

(Sheet 8 of 8)

Table A2

Channel Volumes Below Normal Pool Elevation, Millions of Cubic Yards

Bendway	Survey Date	Channel Volume	Deposition	Volume Remaining, Percent of Initial
Rattlesnake Bend	7702	20.51	0.000	100
	7808	19.81	0 697	97
	7908	19.68	0.829	96
	8006	18.50	2.013	90
	8108	18.15	2.362	88
	8212			
	8306	17.57	2.942	86
	8409	17.30	3.216	84
	8507	17.69	2.822	86
	8606	16.91	3.597	82
	8707	17.04	3.470	83
Cooks Bend	7810	9.00	0.000	100
	7908	8.82	0.177	98
	8008	8.42	0.573	94
	8108	8.03	0.966	89
	8306	7.34	1.657	82
	8409	7.59	1.405	84
	8509	7.35	1.644	82
	8607	7.33	1.666	81
	8707	7.40	1.600	82
Big Creek	7709	1.09	0.000	100
	7806	1.07	0.020	98
	7908	0.96	0.134	88
	8008	0.79	0.305	72
	8108			
	8306	0.65	0.446	59
	8409			
	8509	0.59	0.500	54
	8607	0.57	0.523	52
	8707	0.57	0.522	52
Hairston Bend	8107	6.05	0.000	100
	8210	5.85	0.198	97
	8308	5.52	0.528	91
	8407			
	8505	5.42	0.631	90
	8606	5.38	0.667	89
	8707	5.25	0.799	87

(Continued)

(Sheet 1 of 3)

Table A2 (Continued)

Bendway	Survey Date	Channel Volume	Deposition	Volume Remaining, Percent of Initial
Columbus	8107	2.00	0.000	100
	8210	2.11	-0.103	105
	8308	2.52	-0.519	126
	8407	2.75	-0.751	137
	8505	2.39	-0.389	119
	8608	2.41	-0.407	120
	8707	2.31	-0.306	115
Stinson Creek	8104	2.21	0.000	100
	8210	2.13	0.081	96
	8308	1.85	0.358	84
	8409			
	8507	1.88	0.328	85
	8608	1.79	0.420	81
	8708	1.79	0.417	81
Town Creek	8104	1.79	0.000	100
	8210	1.81	-0.022	101
	8308	1.63	0.156	91
	8410			
	8507	1.71	0.079	96
	8609	1.64	0.145	92
	8708	1.62	0.167	91
Buttahatchee River	8104	1.97	0.000	100
	8211	1.83	0.136	93
	8308	1.67	0.299	85
	8411	1.80	0.167	92
	8507	1.62	0.347	82
	8608			
	8708	1.54	0.421	79
Vinton	8104	0.86	0.000	100
	8212	0.79	0.065	92
	8309	0.64	0.222	74
	8410	0.63	0.228	73
	8506	0.60	0.256	70
	8608			
	8708	0.59	0.270	69
Denmon Creek	8104	0.44	0.000	100
	8212	0.57	-0.137	131
	8309	0.40	0.040	91
	8410	0.37	0.068	84

(Continued)

(Sheet 2 of 3)

Table A2 (Concluded)

Bendway	Survey Date	Channel Volume	Deposition	Volume Remaining, Percent of Initial
Denmon Creek	8506	0.34	0.094	78
	8608	0.33	0.108	75
	8709	0.35	0.088	80
Cane Creek	8104	0.45	0.000	100
	8212	0.42	0.032	93
	8309	0.34	0.111	75
	8410	0.30	0.152	66
	8506	0.31	0.136	70
	8608	0.32	0.131	71
	8709	0.27	0.181	60
McKinley Creek	8104	1.26	0.000	100
	8212	1.17	0.084	93
	8310	1.01	0.248	80
	8410	1.02	0.237	81
	8506	0.95	0.305	76
	8609	0.91	0.347	72
	8709	0.85	0.403	68
Hickelson Lake	8104	0.43	0.000	100
	8212	0.19	0.241	44
	8310	0.04	0.397	8
	8410	0.02	0.413	5
	8506	0.02	0.414	4
	8609			
	8709	0.02	0.415	4
James Creek	8104	0.84	0.000	100
	8212			
	8310	0.62	0.213	75
	8410	0.60	0.242	71
	8507	0.57	0.263	69
	8612	0.61	0.225	73
	8709	0.53	0.303	64

(Sheet 3 of 3)

Table A3

Dredging Activities on the River Section of the Tennessee-Tombigbee Waterway, 1986-87

Navigation Mile	Placement Area	Date Dredged	Dredged Volume cu yd
		1986	
Mile 366	AB-12	8/86	54,641
Mile 332	AL-15	8/86	2,525
Mile 329	AL-14	8/86	3,780
Mile 326	AL-13	8/86	10,703
Mile 321	AL-9	8/86-9/86	18,143
Mile 306	G-26	9/86	6,437
Mile 353.4	C-19	6/86	16,298
Mile 344.8	C-10	6/86	11,966
Mile 265.2	D-36	6/86	69,860
		1987	
Mile 365.9-366	AB-12	5/87	193,324
Mile 353	C-19	5/87	115,129
Mile 349.5	C-14	5/87-6/87	97,819
Mile 333.4	AL-16	6/87	30,900
Mile 326	AL-13	6/87	43,896
Mile 300	G-21	6/87	117,797
Mile 295	G-18	6/87-7/87	3,833
Mile 289	G-14	7/87	96,960
Mile 288	G-14	7/87	38,409
Mile 265.5	D-36	7/87-8/87	24,167
Mile 262.2	D-33	8/87	77,794
Mile 248.6	D-24	8/87	35,774
Mile 260.7	D-30	8/87-9/87	54,734
Mile 257.8	D-30	9/87	57,468
Mile 243	D-20	9/87	63,629
Mile 244	D-20	9/87	20,037
Mile 303.2*	Ringo Bluff/ Owl Creek	8/87-9/87	18,582
Mile 348.3**	McKinley Creek	7/87-8/87	87,381
Mile 319†	Hairston Bend	6/87-7/87	30,527

Source: Mr. Rick Saucer, Tennessee-Tombigbee Waterway Management Center.
* Material pumped into upper end of Owl Creek bendway.
** Upper 3,500 ft of bendway dredged.
† Upper 2,000 ft of bendway dredged.

Table A4

List of Aerial Photographs Used in This Study

Site Number	Photo Date*	Photo Number	Size in.	Source**
A1	400820	EM-3A-63	18	NA
A1	400820	EM-3A-78	18	NA
A1	491105	EM-2F-99	18	ASCS
A1	491105	EM-5F-6	18	ASCS
A1	551104	EM-4P-173	18	ASCS
A1	651008	481196	18	CESWL
A1	730119	259880	15	CESWL
A1	750404	VDTY	30	USGS
A1	830207	NHAP82 291 25L	24	ASCS
A3	580712	AWO-12V-57	18	ASCS
A3	580712	AWO-12V-91	18	ASCS
A3	641008	AWO-3FF-117	18	ASCS
A3	641008	AWO-3FF-78	18	ASCS
A3	720322	40145 272 1004C	18	ASCS
A3	840720	40145 2884 26R	24	ASCS
A6	720314	249 822	9	CESWL
A6	720314	249 824	9	CESWL
A6	720314	249 826	9	CESWL
A6	720314	249 863	9	CESWL
A6	771209	312 359	9	CESWL
A6	771209	312 360	9	CESWL
A6	771209	312 361	9	CESWL
A6	771209	312 395	9	CESWL
A6	870209	372 440	9	CESWL
A6	870209	372 494	9	CESWL
A6	870209	372 495	9	CESWL
A6	870209	372 496	9	CESWL
A8	560918	142 200	9	CESWL
A8	560918	142 202	9	CESWL
A8	620213	4-163 388	9	CESWL
A8	620213	4-163 389	9	CESWL
A8	870208	372 305	9	CESWL
A8	870208	372 307	9	CESWL
A9	581112	EM 4W 187	9	ASCS
A9	581112	EM 4W 189	9	ASCS
A9	581219	EM 6W 144	9	ASCS
A9	581219	EM 6W 146	9	ASCS
A9	651008	196 481	18	CESWL

(Continued)

* Year, month, date.

** NA = not available; ASCS = US Agricultural Stabilization and Conservation Service; CESWL = USAED, Little Rock; USGS = US Geological Survey; NCIC = National Cartographic Information Center, USGS; and CESAM = USAED, Mobile.

(Sheet 1 of 7)

Table A4 (Continued)

Site Number	Photo Date	Photo Number	Size in.	Source
A9	651008	196 483	18	CESWL
A9	651008	196 492	18	CESWL
A9	680919	226 607	9	CESWL
A9	680919	226 609	9	CESWL
A9	680919	226 618	9	CESWL
A9	680919	226 620	9	CESWL
A9	680919	226 631	9	CESWL
A9	680919	226 633	9	CESWL
A9	690304	EM 1KK 125	9	ASCS
A9	690304	EM 1KK 127	9	ASCS
A9	690319	EM 5KK 106	9	ASCS
A9	690319	EM 5KK 108	9	ASCS
A9	730119	259 878	15	CESWL
A9	730119	259 880	15	CESWL
A9	730119	259 930	15	CESWL
A9	730119	259 932	15	CESWL
A9	751021	299 433	9	CESWL
A9	751021	299 473	9	CESWL
A9	751021	299 475	9	CESWL
A9	751021	299 477	9	CESWL
A9	751021	299 515	9	CESWL
A9	751021	299 517	9	CESWL
A9	840108	42-333 1861	9	CESWL
A9	840108	42-333 1863	9	CESWL
A9	840108	42-333 1865	9	CESWL
A9	840108	42-333 2229	9	CESWL
A9	840108	42-333-2231	9	CESWL
A9	840108	42-333 2233	9	CESWL
A9	840108	42-333 2250	9	CESWL
A9	840108	42-333 2252	9	CESWL
A9	840108	42-333 2254	9	CESWL
A10	551008	Mosaic	20	CESWL
A10	601201	BPV1BB 65	9	ASCS
A10	601201	BPV1BB 67	9	ASCS
A10	641003	Mosaic	20	CESWL
A10	661012	Mosaic	20	CESWL
A10	711026	Mosaic	16	CESWL
A10	730129	Mosaic	33	CESWL
A11	630613	176-4 863	9	CESWL
A11	630613	176-4 881	9	CESWL
A11	630613	176-4 883	9	CESWL
A11	650220	196 203	15	CESWL
A11	661025	II 5HH 41	9	ASCS
A11	721217	259 261	15	CESWL
A11	721217	259 263	15	CESWL

(Continued)

(Sheet 2 of 7)

Table A4 (Continued)

Site Number	Photo Date	Photo Number	Size in.	Source
A11	751113	299 1010	9	CESWL
A11	751113	299 1012	9	CESWL
A11	751110	299 972	9	CESWL
A11	751110	299 974	9	CESWL
A11	811223	325 1167	9	CESWL
A11	811223	325 1169	9	CESWL
A12	601110	160-3 575	9	CESWL
A12	601110	160-3 577	9	CESWL
A12	601110	160-3 586	9	CESWL
A12	601110	160-3 588	9	CESWL
A12	630529	176-2 335	9	CESWL
A12	630529	176-2 337	9	CESWL
A12	680910	226 430	9	CESWL
A12	680910	226 432	9	CESWL
A12	680910	226 449	9	CESWL
A12	680910	226 451	9	CESWL
A12	721227	259 407	15	CESWL
A12	721227	259 409	15	CESWL
A13	720322	40131 272 153D	18	ASCS
A13	840720	40131 2784 153BC	24	ASCS
BW1	361019	EE-4-312	18	NA
BW1	500223	EE-3G-21	18	ASCS
BW1	550425	EE-6P-179	18	ASCS
BW1	651023	EE-3GG-9	18	ASCS
BW1	811117	1065 182 85EC	18	ASCS
BW2	500223	EE-3G-21	18	ASCS
BW2	550425	EE-6P-179	18	ASCS
BW2	651023	EE-3GG-9	18	ASCS
BW2	811117	1065 182 85EC	18	ASCS
BW3	391102	EE-1-116	18	NA
BW3	500223	EE-3G-5	18	ASCS
BW3	651017	EE-2GG-37	18	ASCS
BW3	740512	1066 274 1328	18	ASCS
BW3	811117	1066 182 838	18	ASCS
BW4	361127	EE-6-508	18	NA
BW4	500223	EE-3G-7	18	ASCS
BW4	600321	EE-11AA-162	18	ASCS
BW4	811117	1066 182 79L	18	ASCS
BW4	870920	NHAP2 75 61EC	24	ASCS
M1	500407	AVN 2F 124	9	ASCS
M1	500407	AVN 2F 155	9	ASCS
M1	500407	AVN 2F 157	9	ASCS
M1	500407	AVN 2F 159	9	ASCS
M1	500821	AVN 1F 124	9	ASCS
M1	500821	AVN 1F 176	9	ASCS

(Continued)

(Sheet 3 of 7)

Table A4 (Continued)

Site Number	Photo Date	Photo Number	Size in.	Source
M1	500821	AVN 1F 190	9	ASCS
M1	500821	AVN 1F 192	9	ASCS
M1	500821	AVN 1F 194	9	ASCS
M1	540226	AVN 4N 109	9	ASCS
M1	540226	AVN 4N 111	9	ASCS
M1	540226	AVN 4N 113	9	ASCS
M1	540226	AVN 4N 115	9	ASCS
M1	540226	AVN 4N 143	9	ASCS
M1	540226	AVN 4N 145	9	ASCS
M1	540226	AVN 4N 147	9	ASCS
M1	540226	AVN 4N 149	9	ASCS
M1	540226	AVN 4N 171	9	ASCS
M1	540226	AVN 4N 173	9	ASCS
M1	540226	AVN 4N 175	9	ASCS
M1	540226	AVN 4N 177	9	ASCS
M1	540226	AVN 4N 195	9	ASCS
M1	571006	AVN 1T 101	9	ASCS
M1	571006	AVN 1T 103	9	ASCS
M1	571006	AVN 1T 105	9	ASCS
M1	571006	AVN 1T 126	9	ASCS
M1	571006	AVN 1T 128	9	ASCS
M1	571006	AVN 2T 157	9	ASCS
M1	571006	AVN 2T 159	9	ASCS
M1	571006	AVN 2T 190	9	ASCS
M1	571006	AVN 2T 192	9	ASCS
M1	571006	AVN 2T 194	9	ASCS
M1	621114	AVN 1CC 112	9	ASCS
M1	621114	AVN 1CC 114	9	ASCS
M1	621114	AVN 1CC 116	9	ASCS
M1	621114	AVN 1CC 118	9	ASCS
M1	621114	AVN 1CC 146	9	ASCS
M1	621114	AVN 1CC 148	9	ASCS
M1	621114	AVN 1CC 150	9	ASCS
M1	621114	AVN 1CC 176	9	ASCS
M1	621114	AVN 1CC 178	9	ASCS
M1	621114	AVN 1CC 180	9	ASCS
M1	621114	AVN 1CC 94	9	ASCS
M1	621114	AVN 1CC 96	9	ASCS
M1	621114	AVN 1CC 98	9	ASCS
M1	661026	AVN 1HH 31	9	ASCS
M1	661026	AVN 1HH 33	9	ASCS
M1	661026	AVN 1HH 35	9	ASCS
M1	661026	AVN 1HH 62	9	ASCS
M1	661026	AVN 1HH 64	9	ASCS

(Continued)

(Sheet 4 of 7)

Table A4 (Continued)

Site Number	Photo Date	Photo Number	Size in.	Source
M1	661026	AVN 1HH 66	9	ASCS
M1	661026	AVN 1HH 95	9	ASCS
M1	661114	AVN 4HH 15	9	ASCS
M1	661114	AVN 4HH 37	9	ASCS
M1	731121	28143-373-15	9	ASCS
M1	731121	28143-373-36	9	ASCS
M1	731121	28143-373-38	9	ASCS
M1	791025	28143-279-42	9	ASCS
M1	791025	28143-279-56	9	ASCS
M1	791025	28143-279-58	9	ASCS
M2	491116	AVO 3G 141	9	ASCS
M2	491116	AVO 3G 208	9	ASCS
M2	491116	AVO 3G 210	9	ASCS
M2	570217	AVO 3T 114	9	ASCS
M2	570217	AVO 3T 120	9	ASCS
M2	570217	AVO 3T 122	9	ASCS
M2	661103	AVO 3HH 19	9	ASCS
M2	661103	AVO 3HH 36	9	ASCS
M2	661103	AVO 3HH 38	9	ASCS
M2	731101	28151-173-300	9	ASCS
M2	791026	28151-179-39	9	ASCS
M2	840129	IR143-046	22	NCIC
M2	840129	IR143-048	22	NCIC
M2	840129	IR145-046	22	NCIC
M2	840129	IR145-048	22	NCIC
M3	591018	CTJ 6T 101	9	ASCS
M3	591018	CTJ 6T 159	9	ASCS
M3	591018	CTJ 6T 161	9	ASCS
M3	591018	CTJ 6T 163	9	ASCS
M3	591018	CTJ 6T 165	9	ASCS
M3	591018	CTJ 6T 97	9	ASCS
M3	591018	CTJ 7T 33	9	ASCS
M3	591018	CTJ 7T 35	9	ASCS
M3	591018	CTJ 7T 37	9	ASCS
M3	591018	CTJ 7T 39	9	ASCS
M3	641007	CTJ 2FF 127	9	ASCS
M3	641007	CTJ 2FF 129	9	ASCS
M3	641007	CTJ 2FF 131	9	ASCS
M3	641007	CTJ 2FF 49	9	ASCS
M3	641007	CTJ 2FF 53	9	ASCS
M3	641007	CTJ 2FF 70	9	ASCS
M3	641007	CTJ 2FF 74	9	ASCS
M3	641007	CTJ 2FF 76	9	ASCS
M3	691115	CTJ 1LL 107	9	ASCS
M3	691115	CTJ 1LL 111	9	ASCS

(Continued)

(Sheet 5 of 7)

Table A4 (Continued)

Site Number	Photo Date	Photo Number	Size in.	Source
M3	691115	CTJ 1LL 124	9	ASCS
M3	691115	CTJ 1LL 126	9	ASCS
M3	691115	CTJ 1LL 128	9	ASCS
M3	691115	CTJ 1LL 130	9	ASCS
M3	691115	CTJ 1LL 181	9	ASCS
M3	691115	CTJ 1LL 183	9	ASCS
M3	751031	22029-176 32	9	ASCS
M3	751031	22029-176 49	9	ASCS
M3	751031	22029-176 51	9	ASCS
M3	770207	VE105-125	9	NCIC
M3	770207	VE105-127	9	NCIC
M3	770207	VE105-129	9	NCIC
M3	770207	VE105-154	9	NCIC
M3	770207	VE105-156	9	NCIC
M3	770207	VE105-158	9	NCIC
M3	770207	VE105-160	9	NCIC
M3	770207	VE106-16	9	NCIC
M3	780327	VE107-86	9	NCIC
M3	780327	VE107-88	9	NCIC
M3	780327	VE107-90	9	NCIC
M3	780327	VE107-92	9	NCIC
M3	780327	VE107-94	9	NCIC
M3	780327	VE107-127	9	NCIC
M3	780327	VE107-129	9	NCIC
M3	820307	22029-181 104	9	ASCS
M3	820307	22029-181 106	9	ASCS
M3	820307	22029-181 133	9	ASCS
O1	400918	Can 336 CMR-53-26	18	NA
O1	520904	DKJ-2G-133	18	ASCS
O1	591019	DKJ-9T-170	18	ASCS
O1	661128	DKJ-1HH-134	18	ASCS
O1	850927	NHAP237146EC	24	ASCS
O1.5	400918	Can 366 CMR-53-79	16	NA
O1.5	520904	DKJ-2G-169	18	ASCS
O1.5	591023	DKJ-10T-181	18	ASCS
O1.5	661128	DKJ-1HH-170	18	ASCS
O1.5	850927	NHAP237146EC	18	ASCS
O2	411011	Can 10653 CTI-3B-51	18	NA
O2	510116	CTI-8G-103	18	ASCS
O2	560518	CTI-1P-21	18	ASCS
O2	610109	CTI-6BB-38	18	ASCS
O2	671118	CTI-2JJ-75	18	ASCS
O2	850208	HAP82-403-55L	24	ASCS
O3	411111	Can 1280 CQK-4A-82	18	NA
O3	510116	CQK-8G-193	18	ASCS

(Continued)

(Sheet 6 of 7)

Table A4 (Concluded)

Site Number	Photo Date	Photo Number	Size in.	Source
03	610109	CQK-6BB-109	18	ASCS
03	671106	CQK-1JJ-272	18	ASCS
03	730210	22073-173-91A	18	ASCS
03	850212	HAP82-403-66L	24	ASCS
04	400918	Can 336 CM4-53-87	18	NA
04	520904	DKJ-2G-161	18	ASCS
04	661128	DKJ-1HH-143	18	ASCS
04	661128	DKJ-1HH-161	18	ASCS
04	720219	22025-272-98A	18	ASCS
04	800124	GS-VESO	9	USGS
R1	631107	CEU-1DD-213	18	ASCS
R1	691129	CEU-2LL-38	18	ASCS
R1	691129	CEU-2LL-43	18	ASCS
R1	781109	5091 178 9 EC	18	ASCS
R2	561229	DLY-4R-177	18	ASCS
R2	620326	DLY-2CC-52	18	ASCS
R2	681015	DLY-2KK-167	18	ASCS
R2	750127	22079 175 56L	18	ASCS
R2	820222	22079 181 73L	18	ASCS
T2	371202	Can 1119 HS-9-42	18	NA
T2	491115	HS-1G-151	18	ASCS
T2	491115	HS-2G-18	18	ASCS
T2	591219	HS-4AA-25	18	ASCS
T2	591219	HS-4AA-79	18	ASCS
T2	651201	HS-2GG-129	18	ASCS
T2	791014	1107-179-105R	18	ASCS
T2	861016	SAM 40-43-739 8 909	9	USGS
T3	370930	Can 1410 ND-4-59	18	NA
T3	520205	ND-10F-54	18	ASCS
T3	631116	ND-3EE-80	18	ASCS
T3	861016	SAM 40-43 739 6 821	9	USGS
T4	370927	Can 1449 NG-6-32	18	NA
T4	520205	NG-10F-27	18	ASCS
T4	581111	NG-7W-150	18	ASCS
T4	690322	NG-2KK-19	18	ASCS
T4	720915	NASA/MSC 36-0117	9	USGS
T4	861016	SAM 43 TO 50 739	9	CESAM

(Sheet 7 of 7)

APPENDIX B: MAPS OF TREE LINES

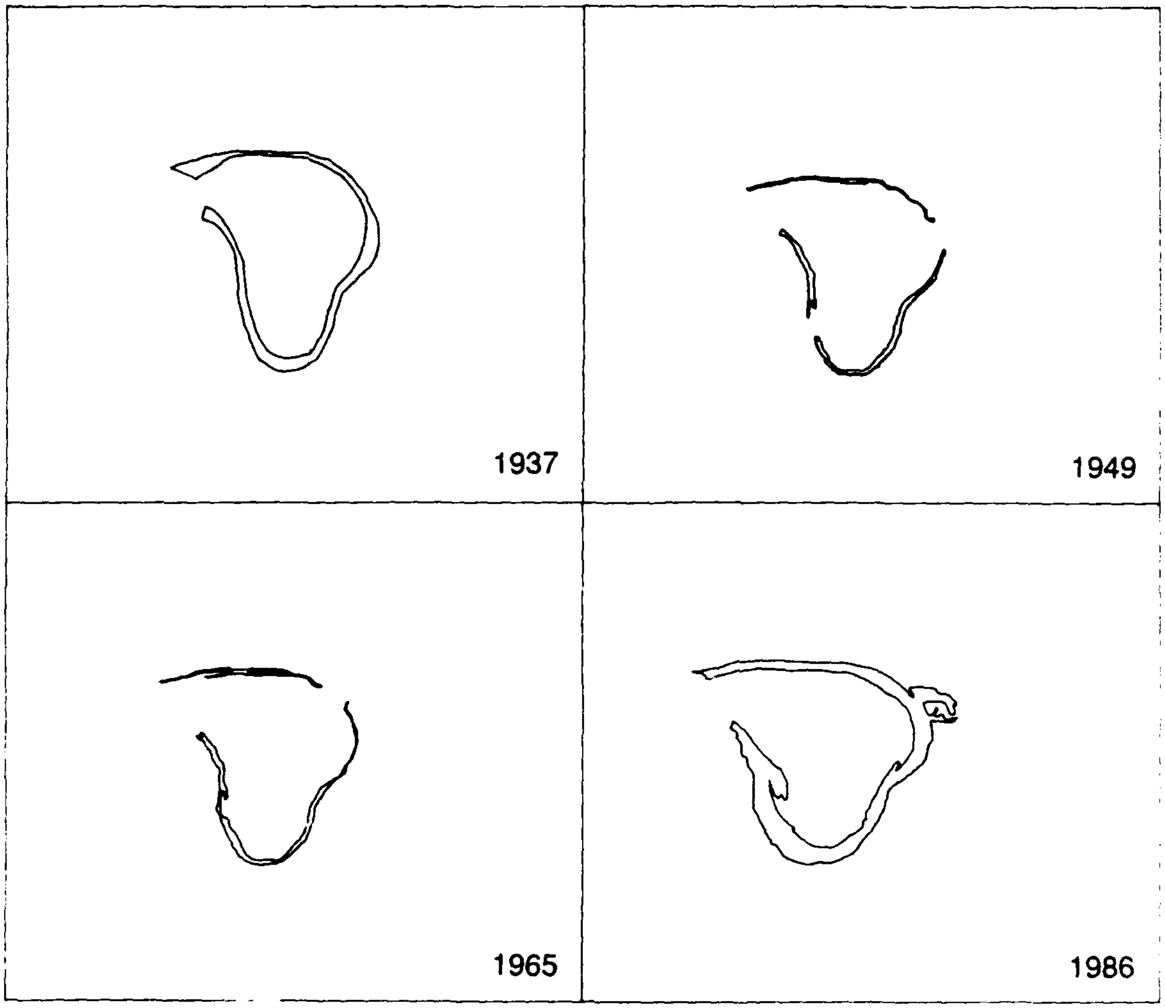


Figure B1. Site T2, Lubbub Creek, Tombigbee River, southwest of Aliceville, AL. Site T2 is a natural oxbow that was cut off before 1937. Gainesville Lock and Dam, located 34 miles downstream, was closed and the navigation pool impounded between October 1978 and April 1979

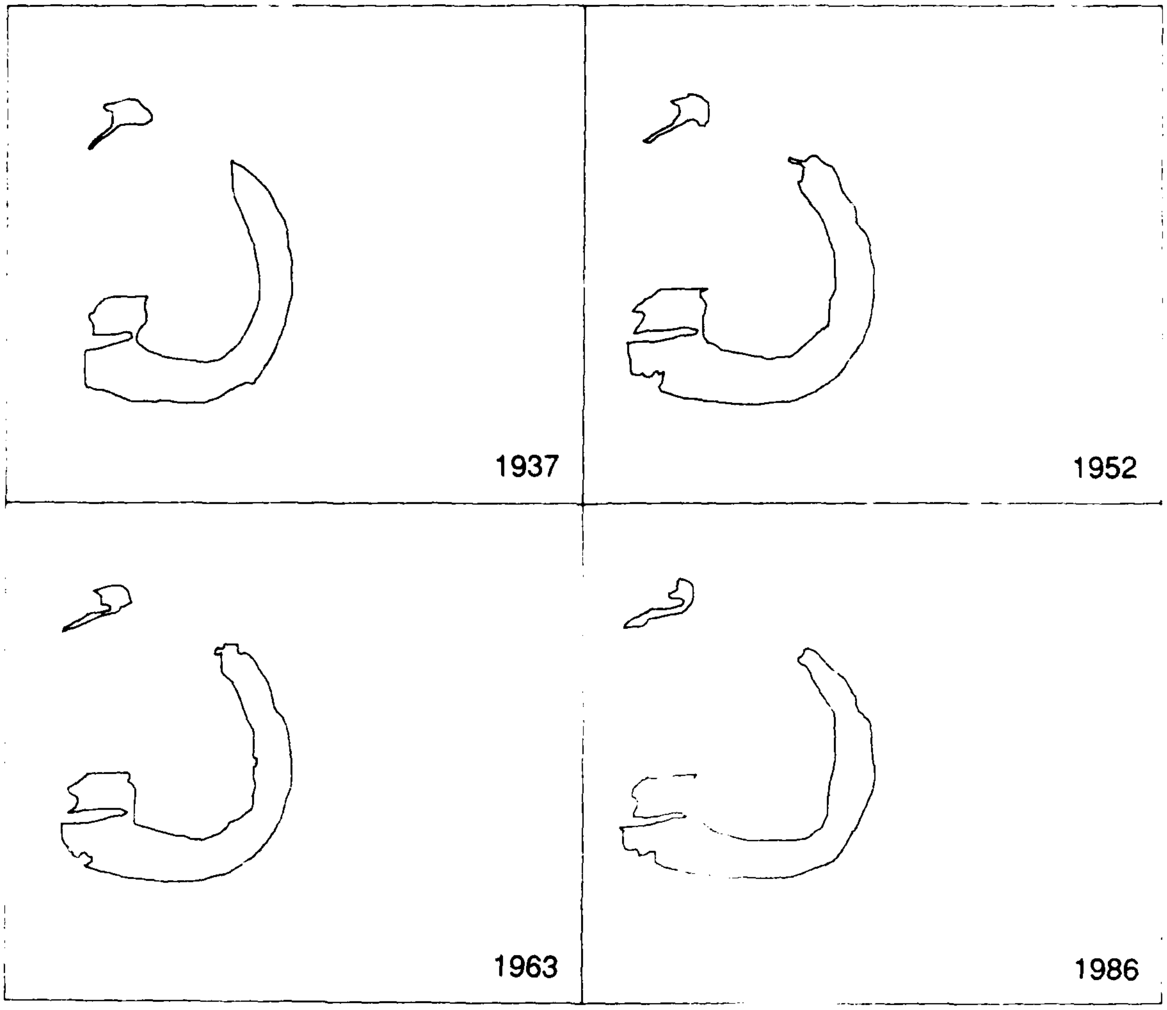


Figure B2. Site T3, Lake Catherine, Tombigbee River, near Columbus, MS. Site T3 is a natural oxbow that was cut off between 1823 and 1938. A small dam was constructed across the southern end of the bendway before 1937

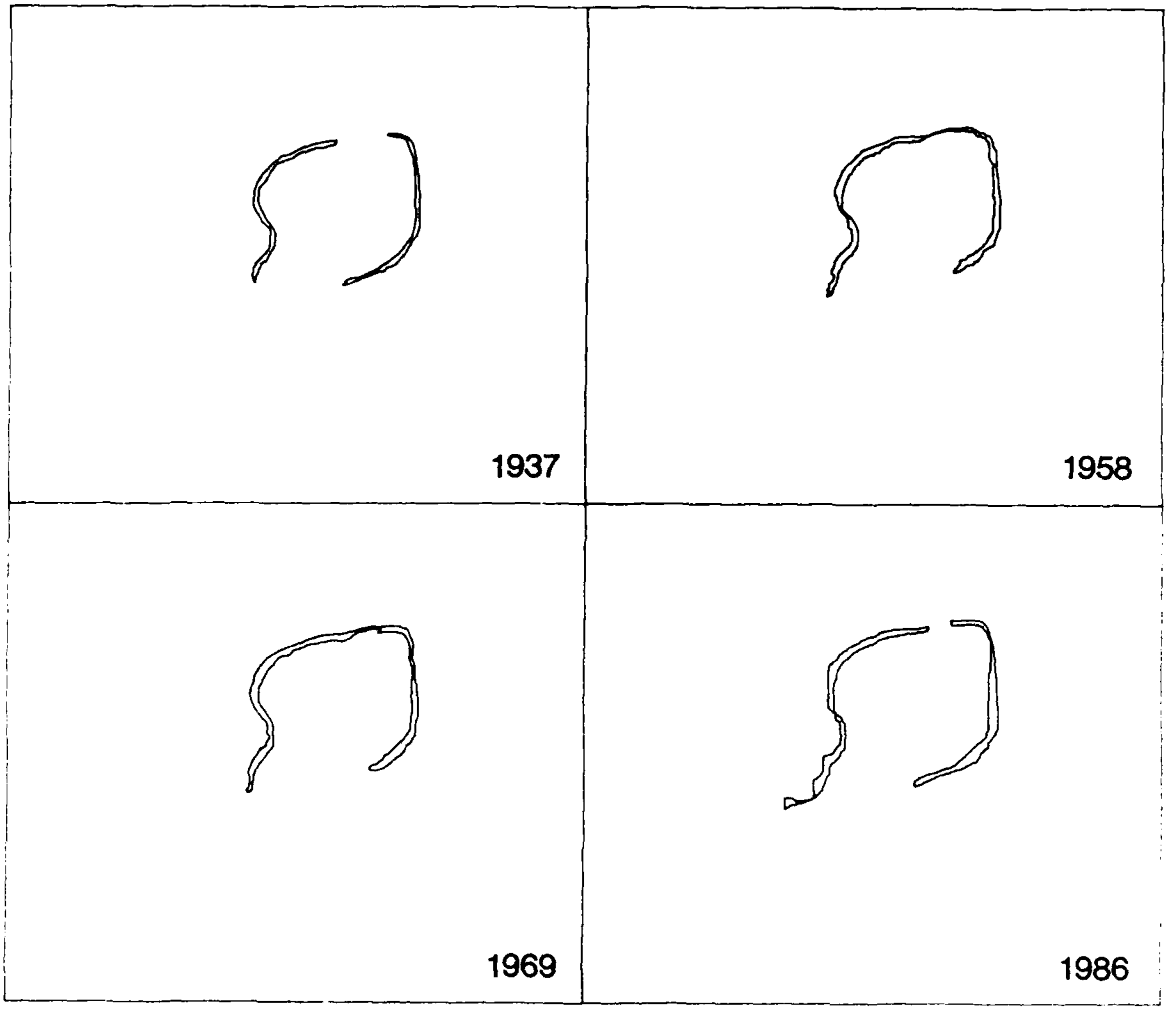


Figure B3. Site T4, Un-named, Tombigbee River, southwest of Amory, MS, and east of the Tombigbee River. Site T4 is a natural oxbow that was cut off before 1938. A small dam was constructed across the western end of the bendway between 1958 and 1969. Columbus Lock and Dam, located downstream on the Tombigbee, was closed and the navigation pool impounded in 1981

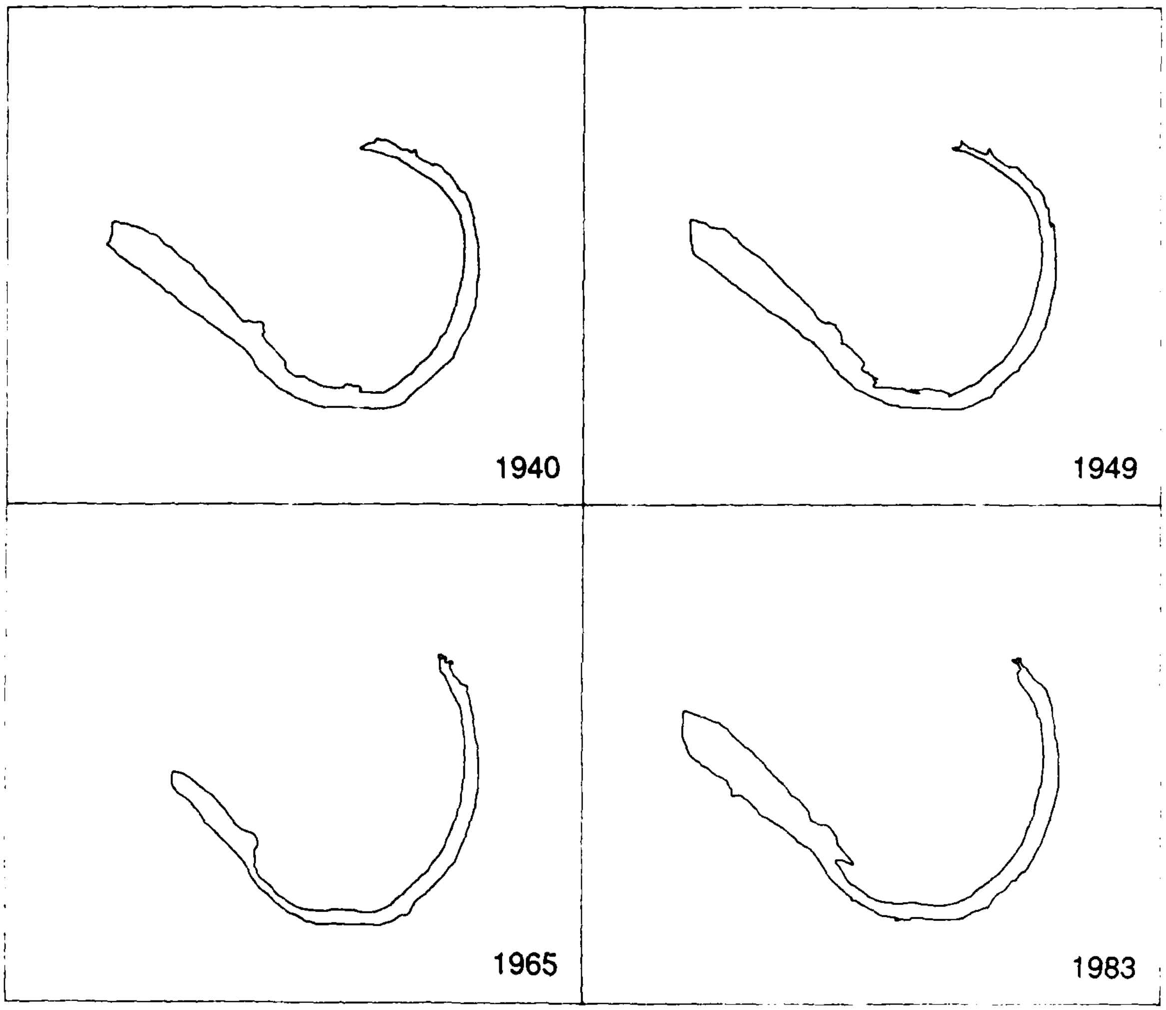


Figure B4. Site A1, Old River Lake, Arkansas River, southwest of Wright, AR. Site A1 is a natural oxbow that was cut off before 1938. Lock and Dam No. 5, located 1.5 miles downstream, was closed and the navigation pool impounded in December 1968

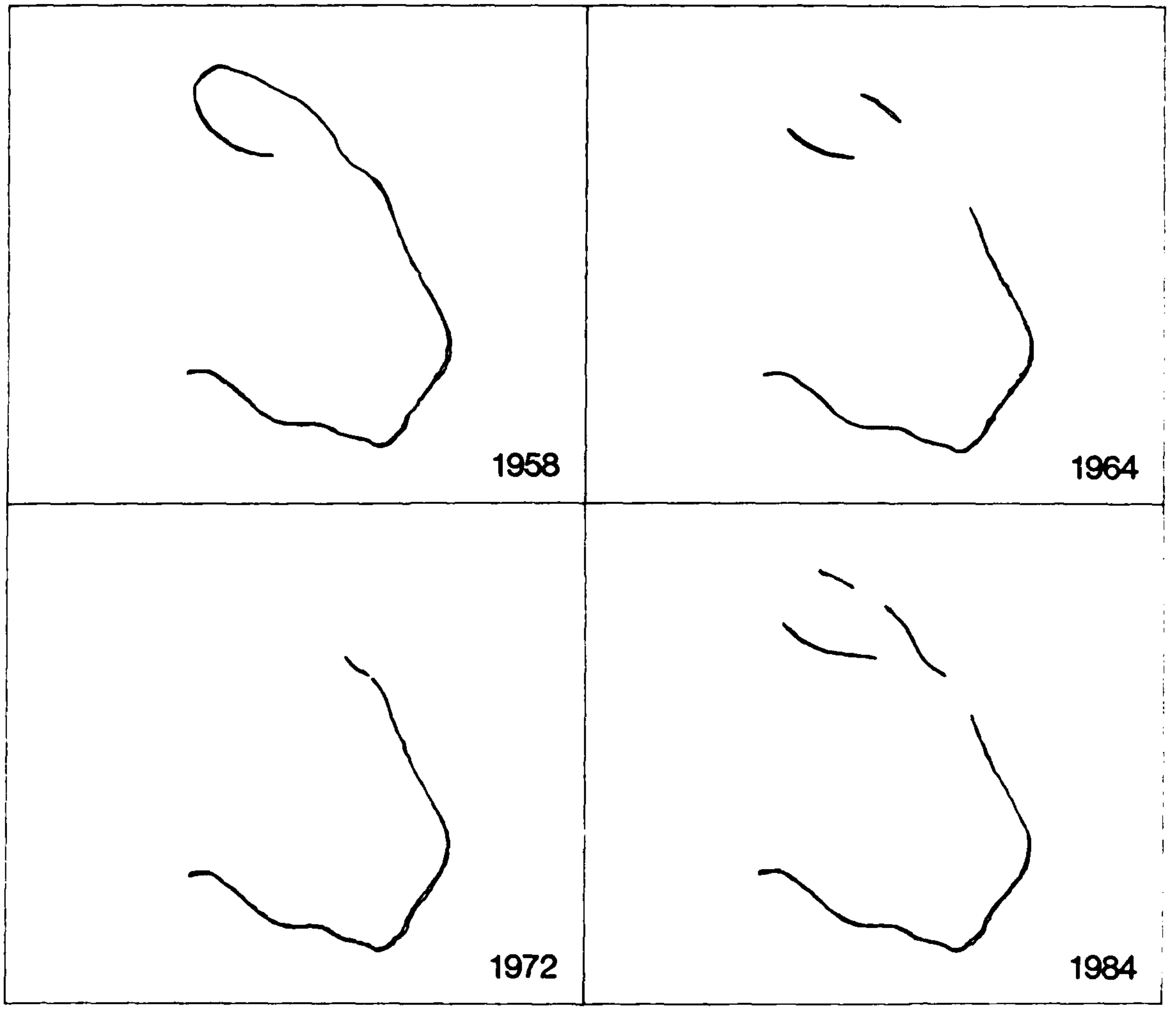


Figure B5. Site A3, Old River Channel, Verdigris River, 14 miles east of Broken Arrow, OK. Site A3 is a natural oxbow that was cut off before 1951. Chouteau Dam, located 16 miles downstream, was closed and the navigation pool impounded before 1972

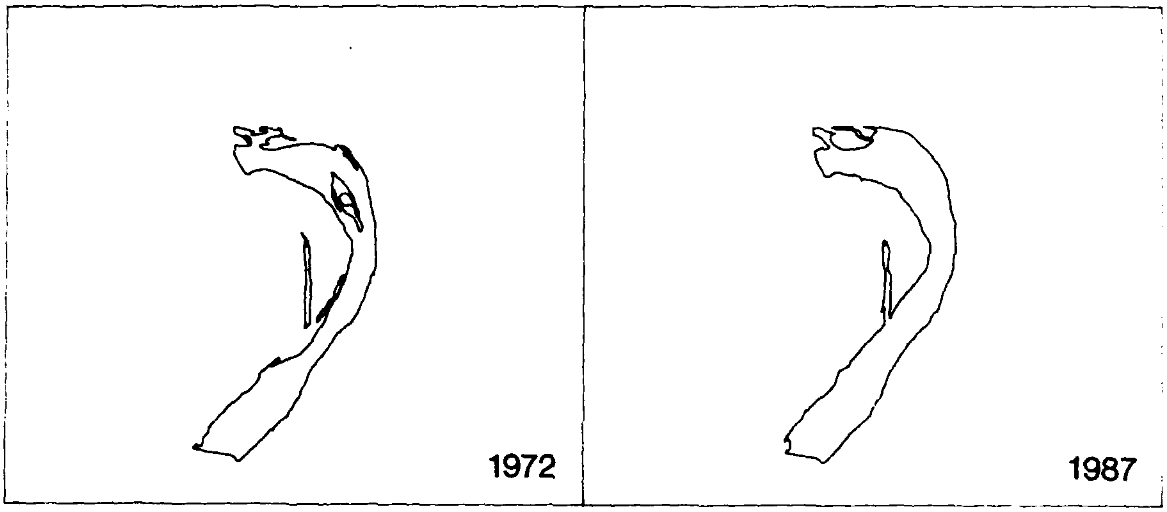


Figure B6. Site A6, Case Bar, Arkansas River, northeast of Woodson, AR. Site A6 is a man-made cutoff constructed in 1962. Lock and Dam No. 5, located about 10 miles downstream, was closed and the navigation pool impounded in December 1968

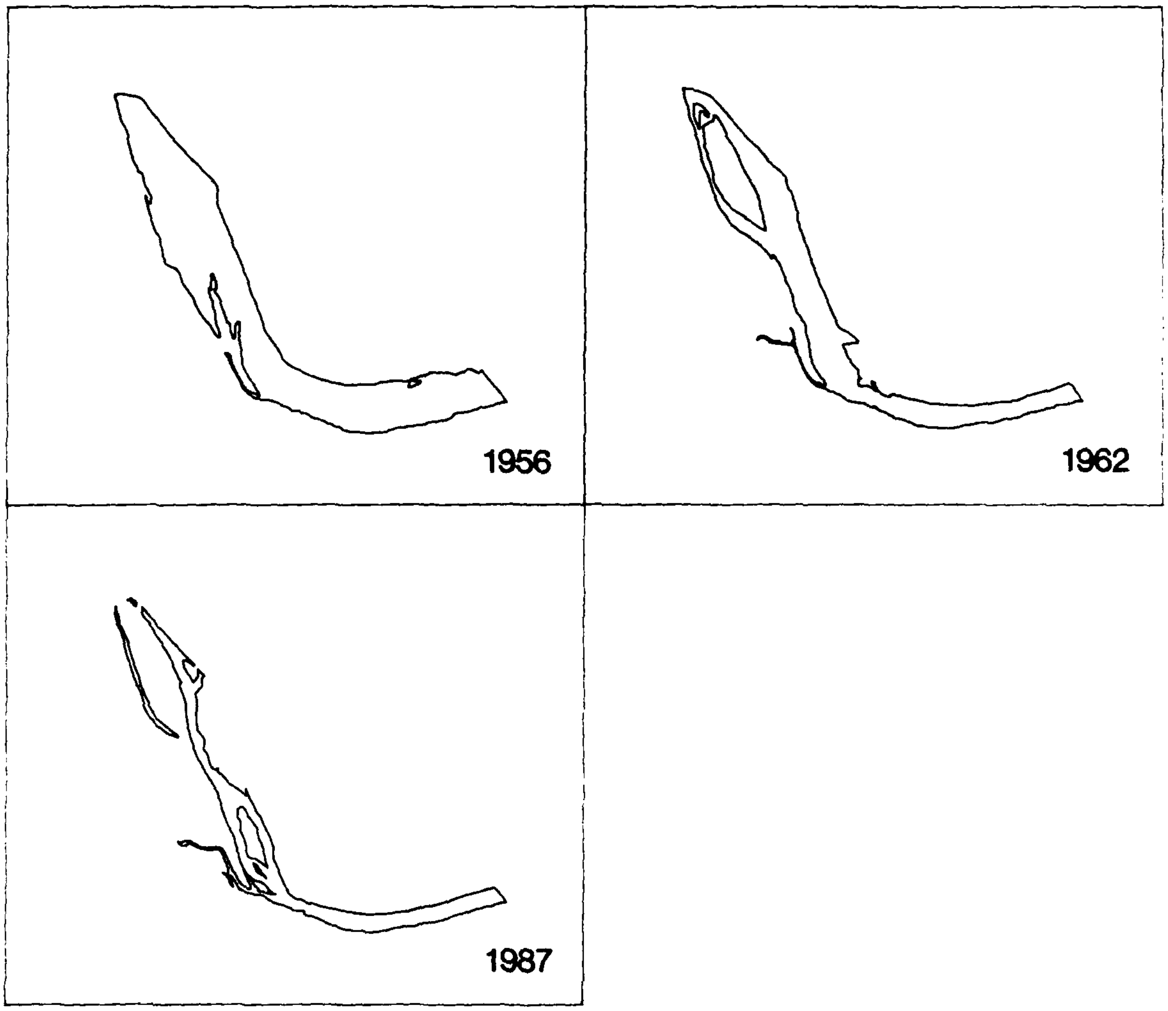


Figure B7. Site A8, Hensley Bar, Arkansas River, northeast of Pine Bluff, AR. Site A8 is a man-made cutoff constructed in 1952. Lock and Dam No. 4, located about 11 miles downstream, was closed and the navigation pool impounded in 1968

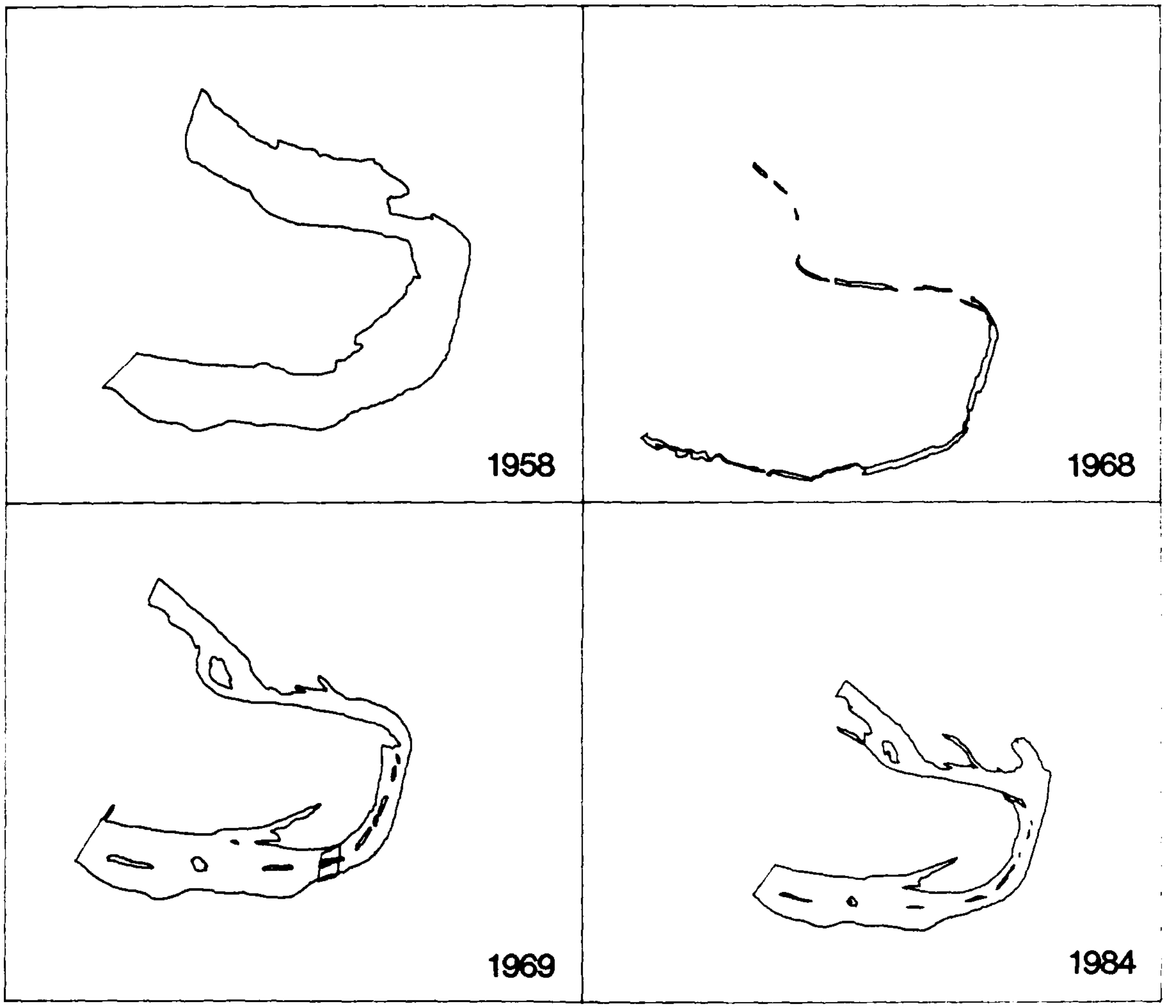


Figure B8. Site A9, Brodie, Arkansas River, northwest of Wright, AR. Site A9 is a man-made cutoff constructed in 1957. Lock and Dam No. 5, located 4 miles downstream, was closed and the navigation pool impounded in December 1968

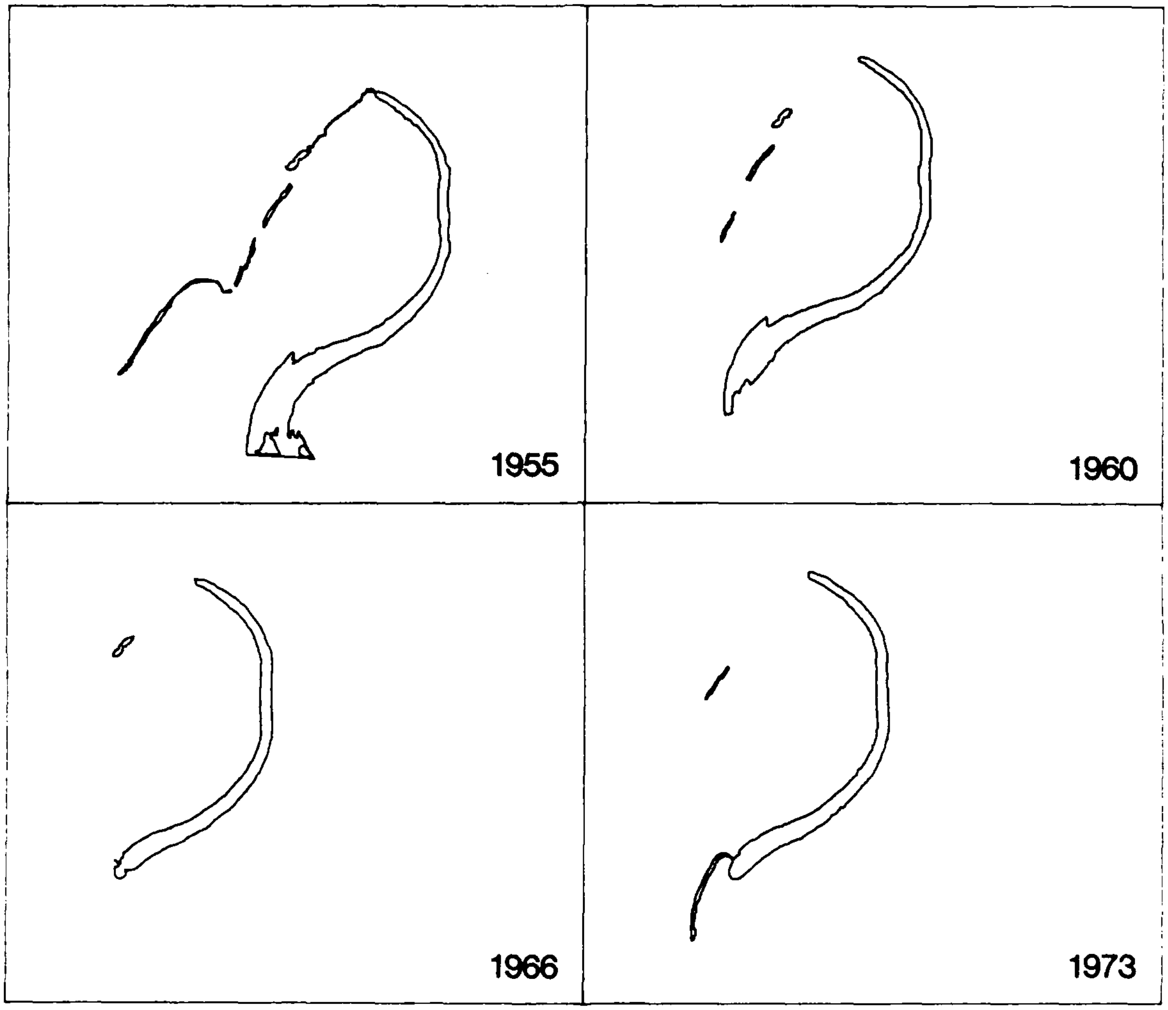


Figure B9. Site A10, Morrilton, Arkansas River, southeast of Morrilton, AR. Site A10 is a man-made cutoff constructed in 1950. Toad Suck Ferry Lock and Dam, located 9.5 miles downstream, was closed and the navigation pool impounded in 1969

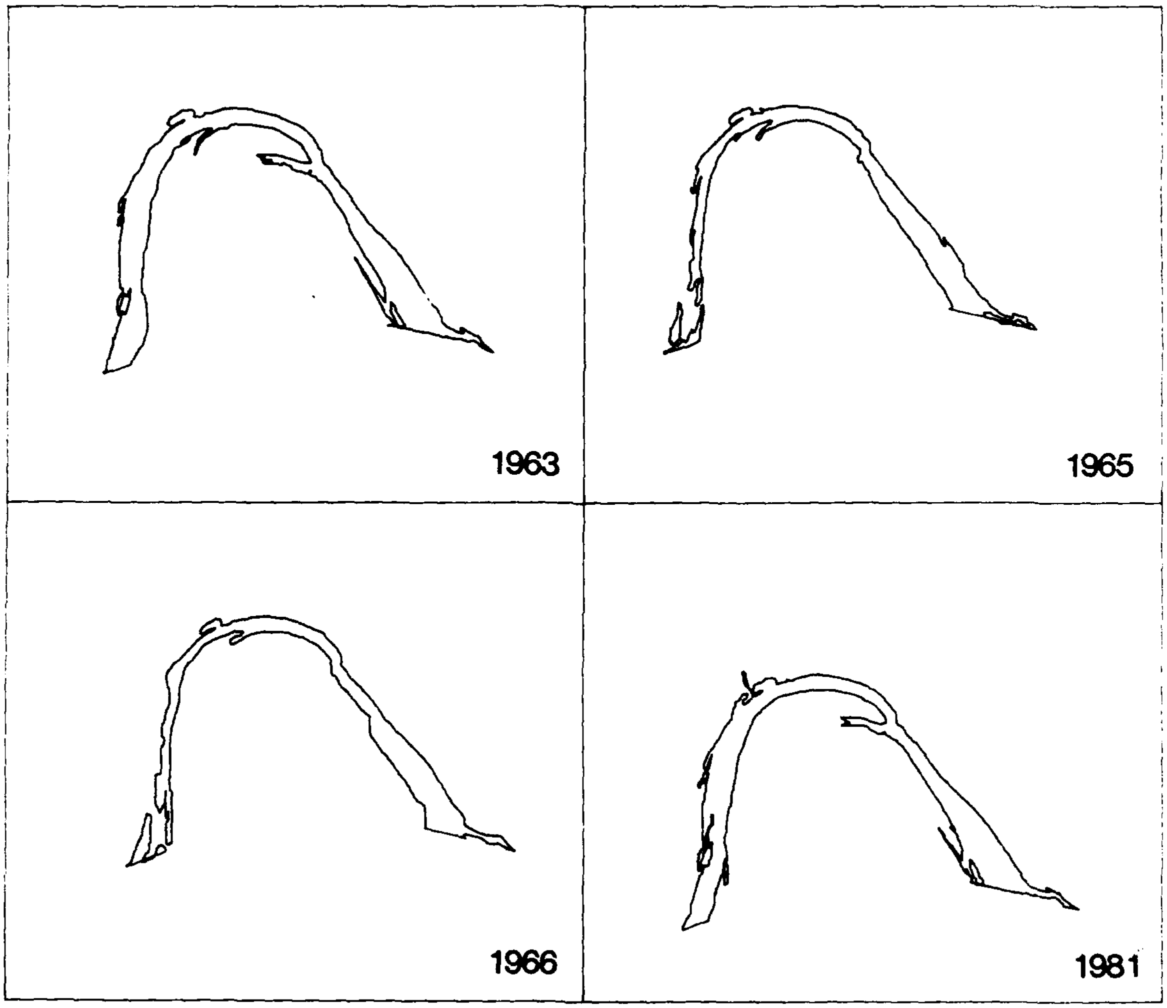


Figure B10. Site A11, McLean, Arkansas River, just south of Coal Hill, AR. Site A11 is a man-made cutoff constructed in 1955. Dardanelle Lock and Dam, located 37.5 miles downstream, was closed and the navigation pool impounded in February 1965

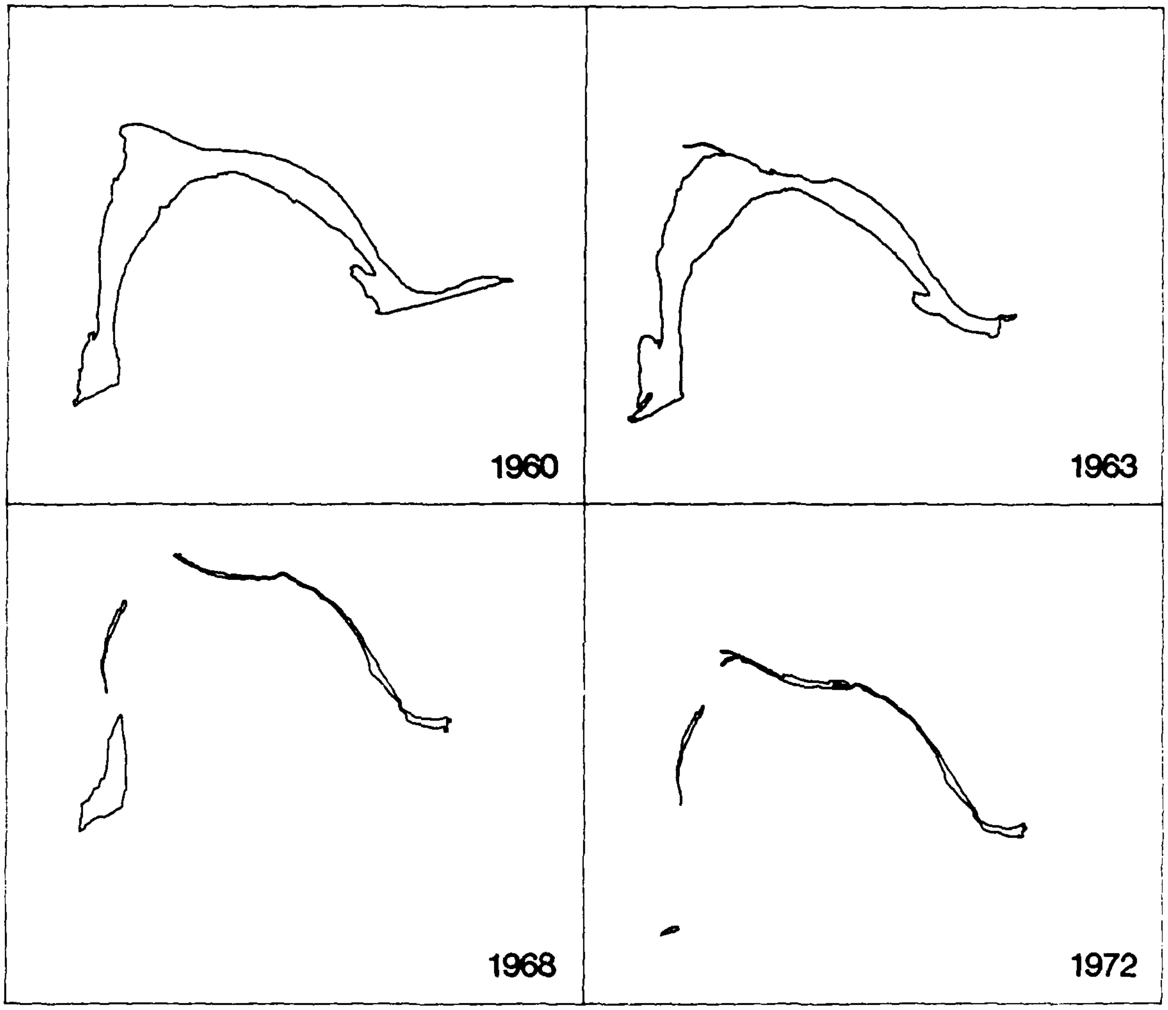


Figure B11. Site A12, Trustee, Arkansas River, just north of Lavaca, AR. Site A12 is a man-made cutoff constructed in 1954. Ozark-Jeta Taylor Lock and Dam, located 27.5 miles downstream, was closed and the navigation pool impounded in February 1965

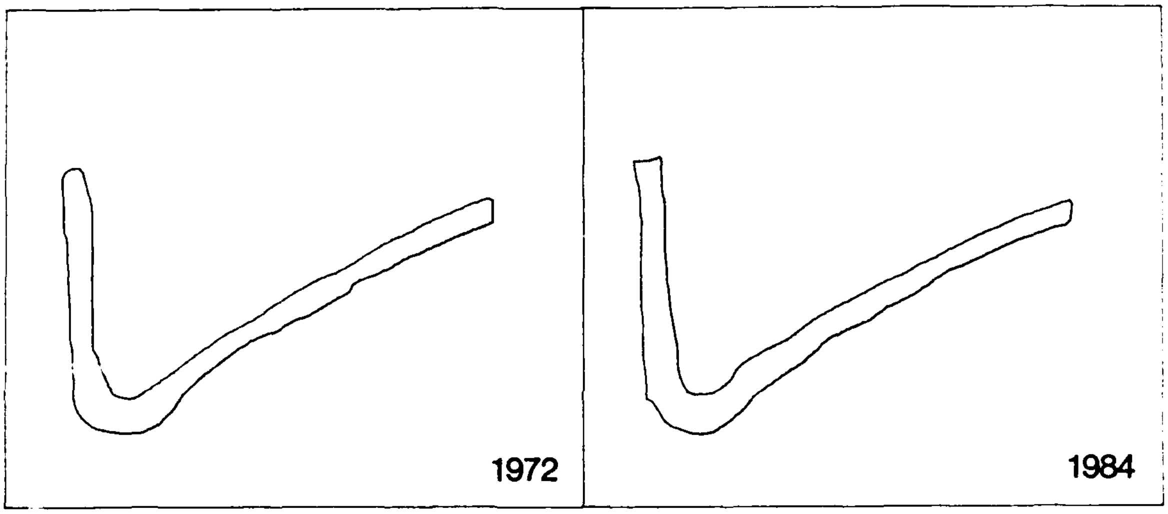


Figure B12. Site A13, Catoosa, Verdigris River, east of Catoosa, OK. Site A13 is a man-made cutoff constructed before 1972. Newt Graham Lock and Dam, located 20 miles downstream, was closed and the navigation pool impounded before 1972

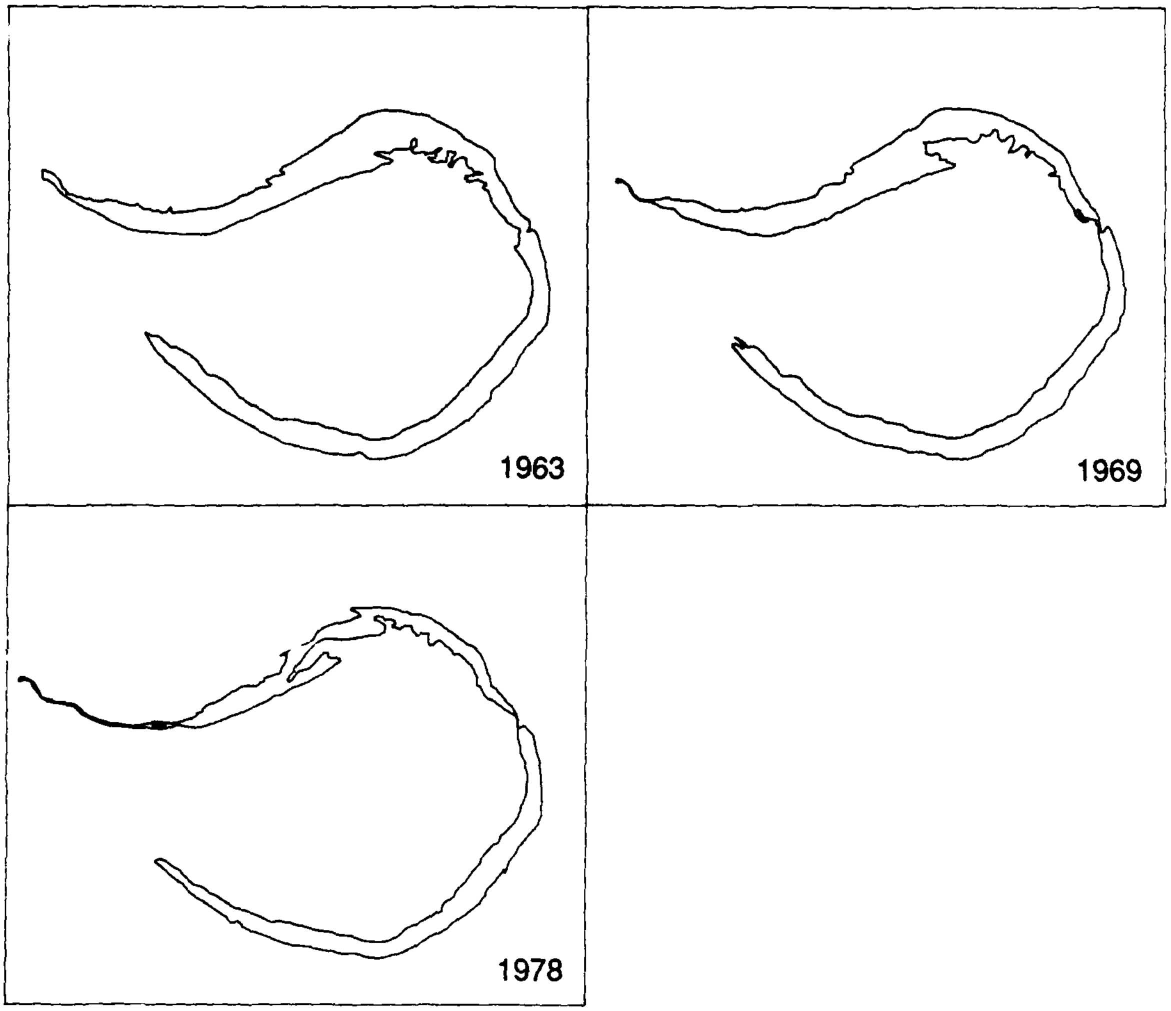


Figure B13. Site R1, Dixon Bend, Red River, near Canfield, AR. Site R1 is a man-made cutoff constructed between 1956 and 1963

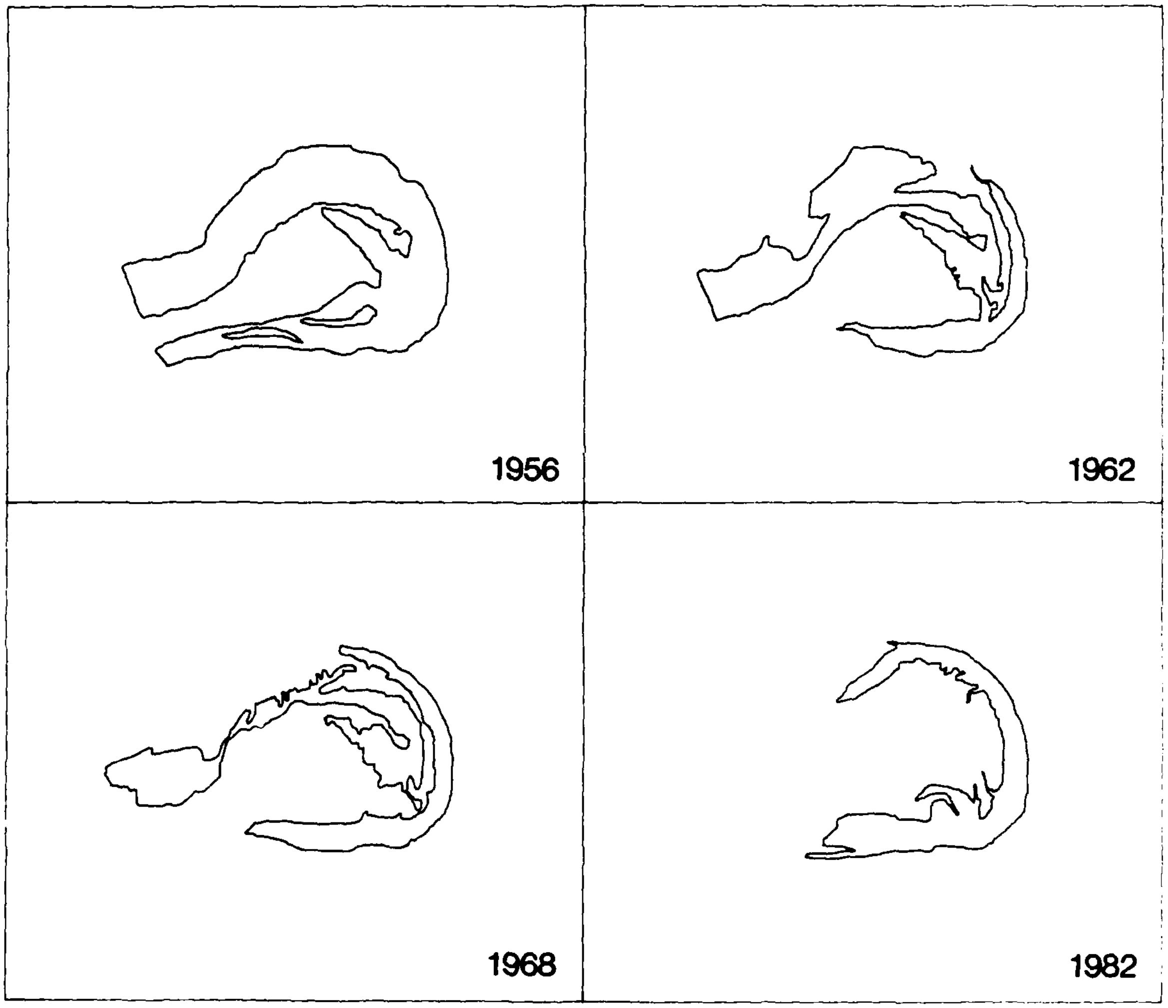


Figure B14. Site R2, McNeeley, Red River, 4 miles north of Boyce, LA.
Site R2 is a man-made cutoff constructed in 1948

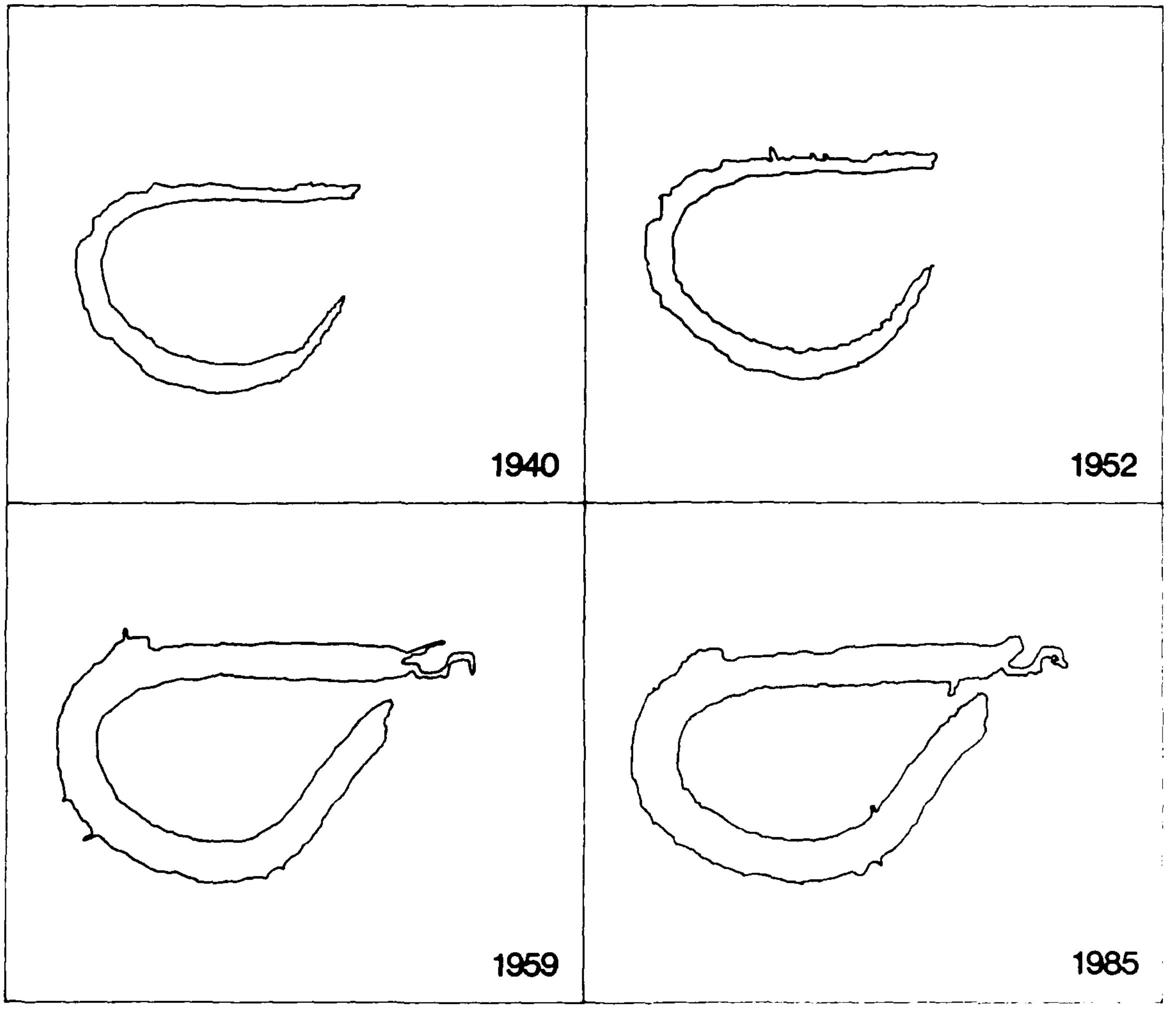


Figure B15. Site 01, Tew Lake, Ouachita River, 9 miles north of Jonesville, LA. Site 01 is a natural oxbow that was cut off before 1938. A small dam was constructed across the northeastern end of the bendway between 1952 and 1959. Jonesville Lock and Dam, located 25 miles downstream, was closed and the navigation pool impounded in March 1972

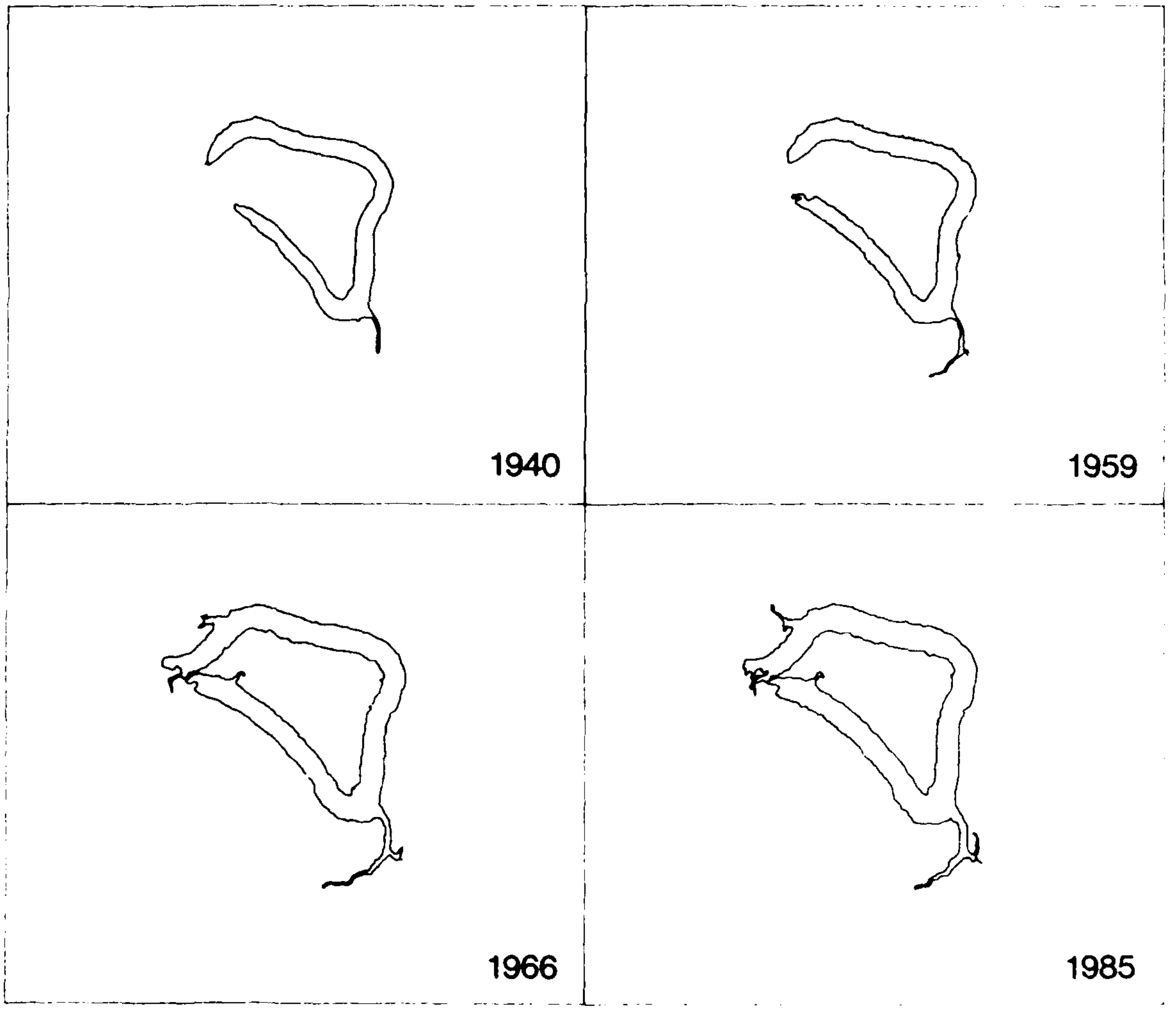


Figure B16. Site 01.5, Mean Lake, Ouachita River, 9 miles north of Jonesville, LA. Site 01.5 is a natural oxbow that was cut off before 1938. Small dams were constructed across both arms of the bendway between 1959 and 1966. Jonesville Lock and Dam, located 25 miles downstream, was closed and the navigation pool impounded in March 1972

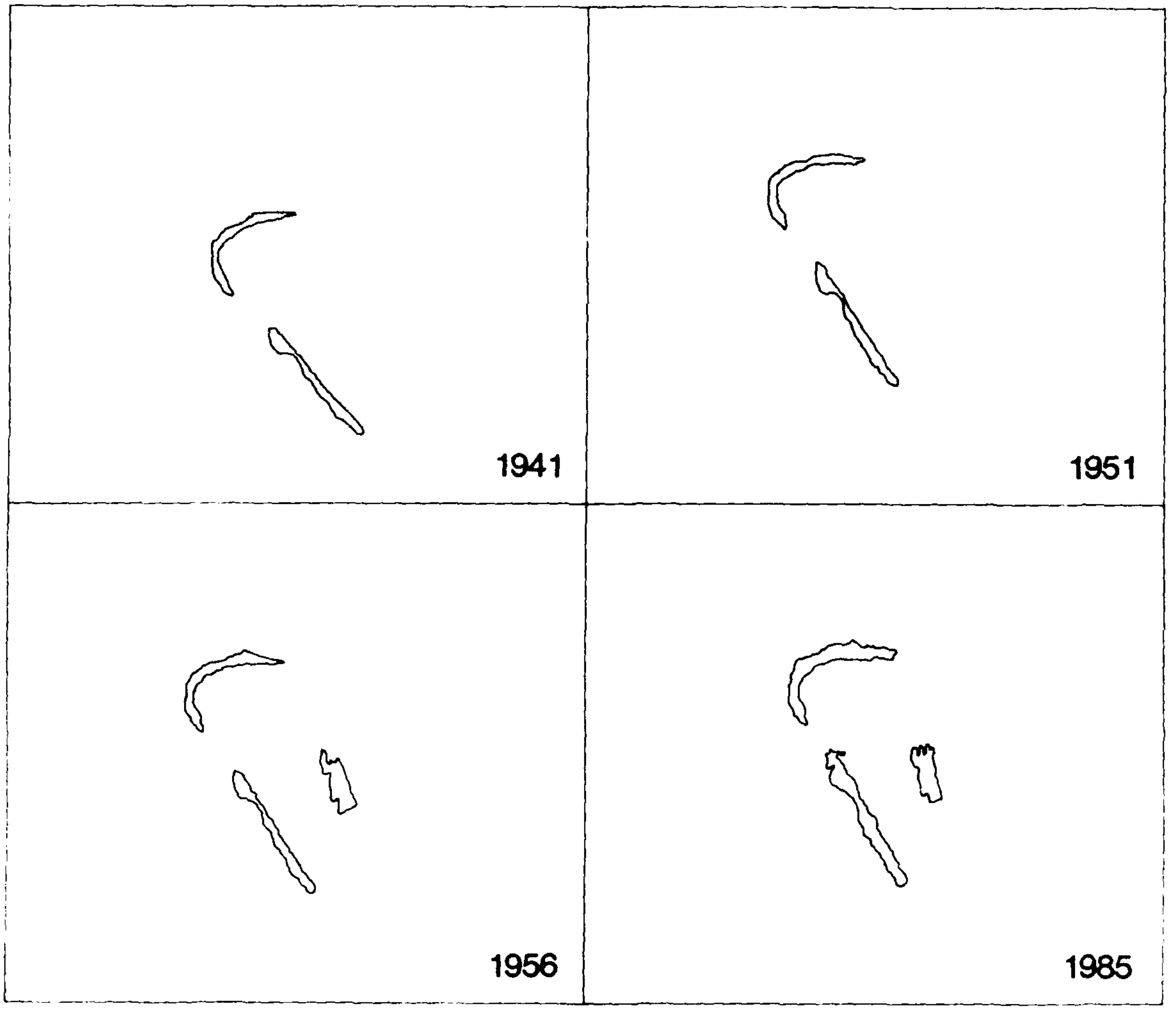


Figure B17. Site 02, Horseshoe Lake, Ouachita River, 7 miles northwest of Columbia, LA. Site 02 is a natural oxbow that was cut off before 1938. A small dam was constructed across the upstream end of the bendway before 1956. Columbia Lock and Dam, located just downstream, was closed and the navigation pool impounded in May 1972

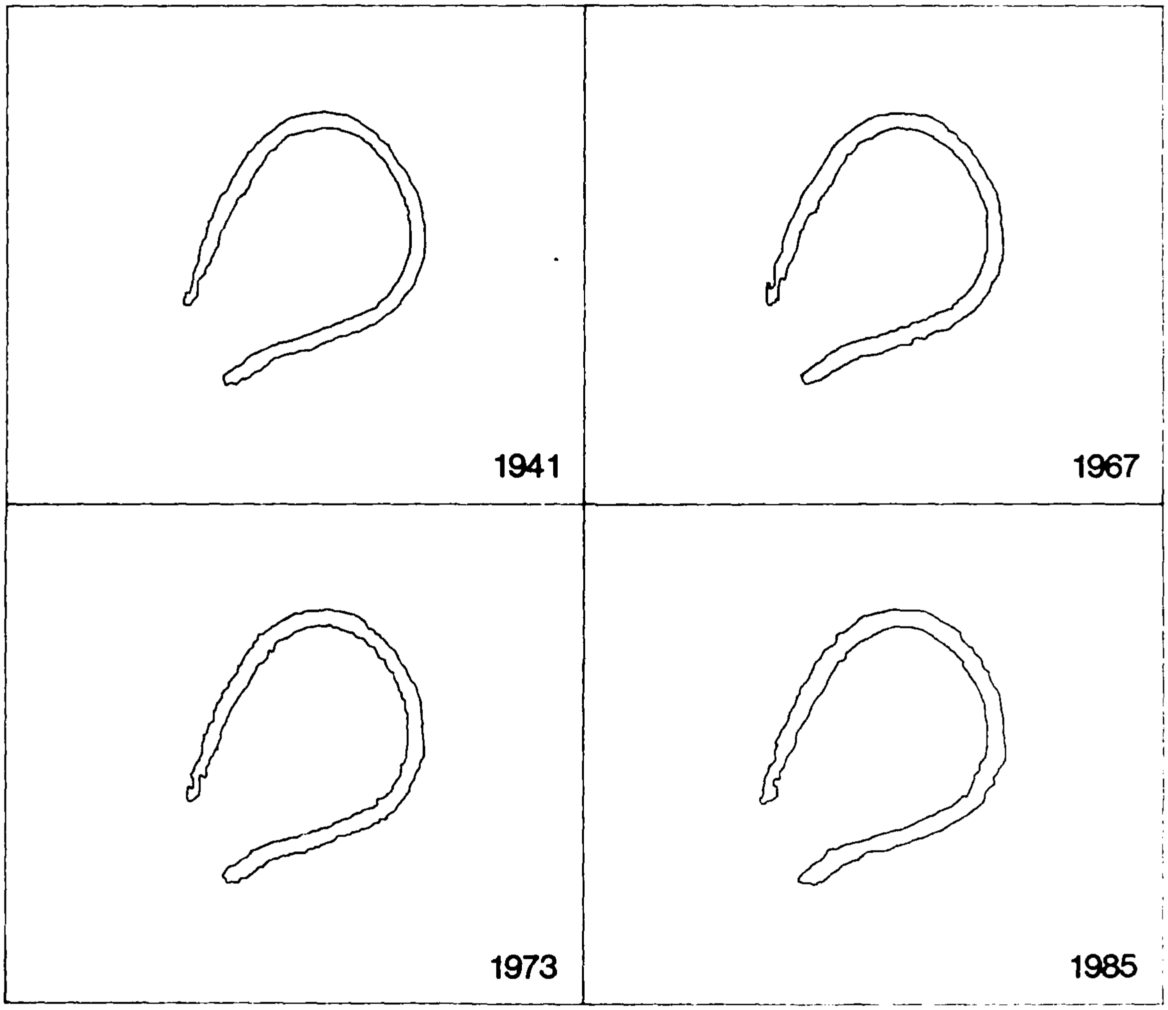


Figure B18. Site 03, Horseshoe Lake, Ouachita River, 10 miles north of Monroe, LA. Site 03 is a natural oxbow that was cut off before 1938. Columbia Lock and Dam, located 63 miles downstream, was closed and the navigation pool impounded in May 1972

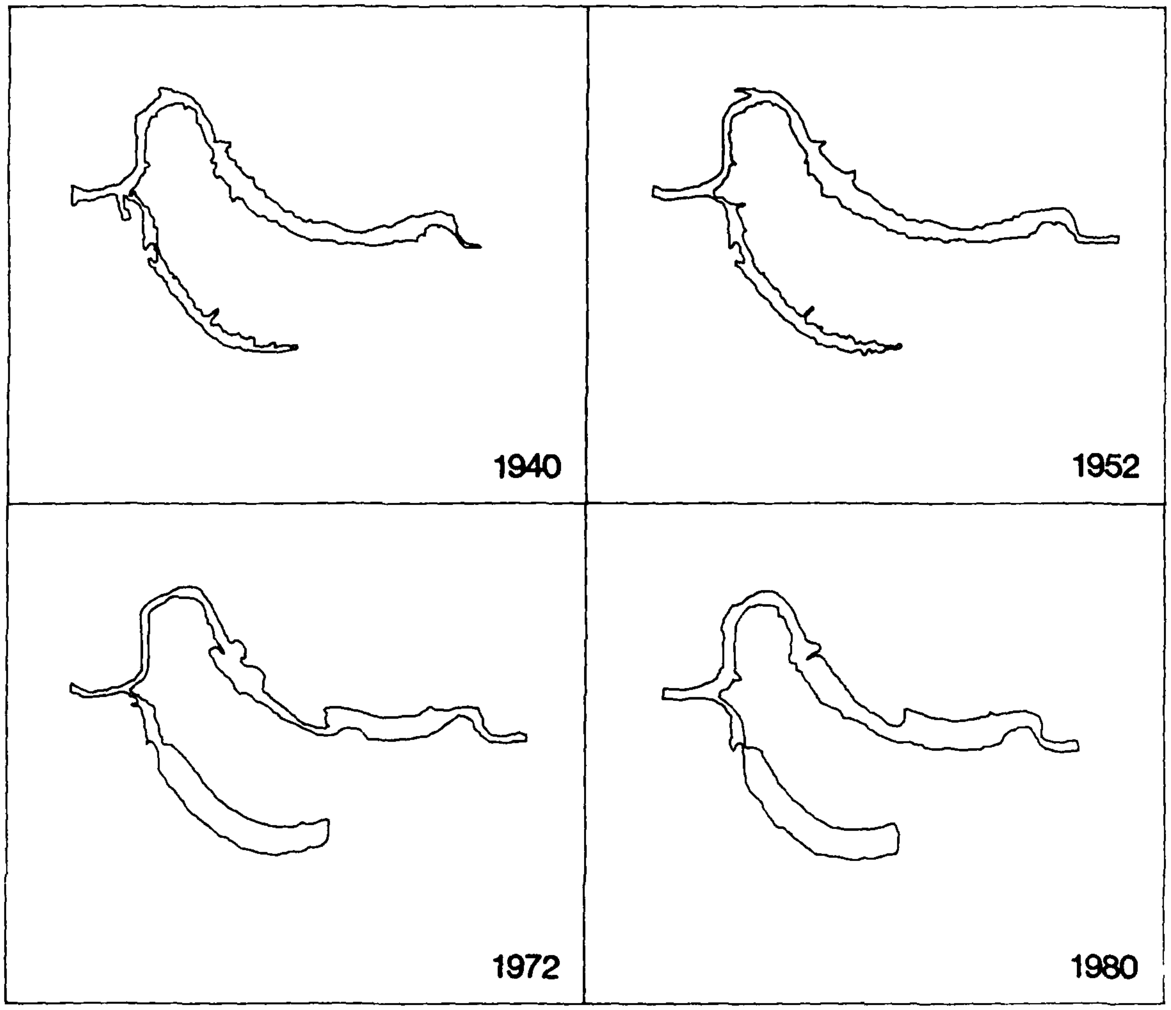


Figure B19. Site 04, Rawson Creek (Dry Lake), Ouachita River, 5 miles north of Harrisonburg, LA. Site 04 is a natural oxbow that was cut off before 1938. Jonesville Lock and Dam, located 38 miles downstream, was closed and the navigation pool impounded in March 1972

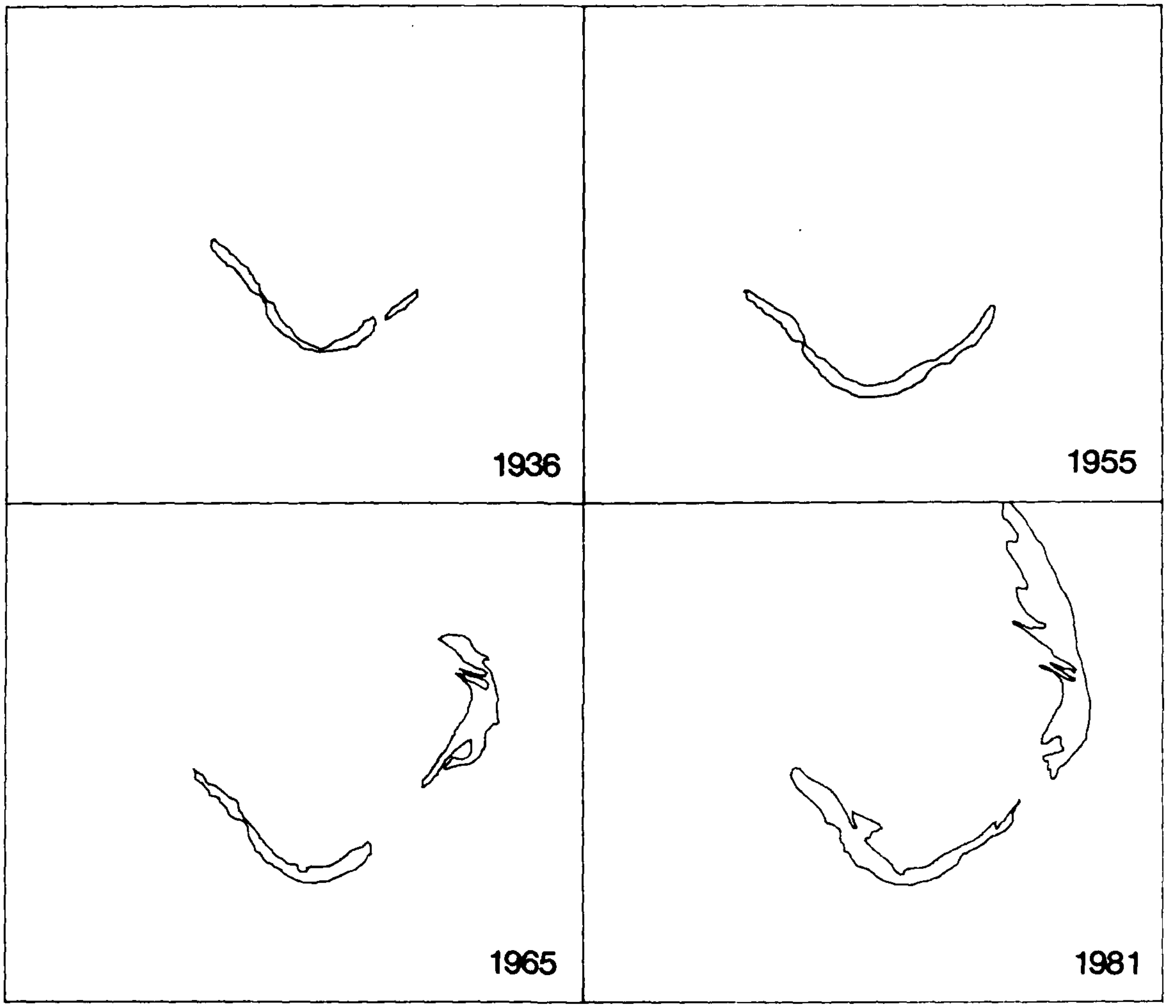


Figure B20. Site BW1, Storer Lake, Black Warrior River, 8 miles northeast of Eutaw, AL. Site BW1 is a natural oxbow that was cut off before 1938. Old Lock and Dam No. 8, located 5 miles downstream, was closed in 1903, providing a 6-ft navigation channel. The dam was raised in the late 1930s to provide a 9-ft navigation channel. Selden Lock and Dam, located 22 miles downstream, was closed and the navigation pool impounded in October 1957

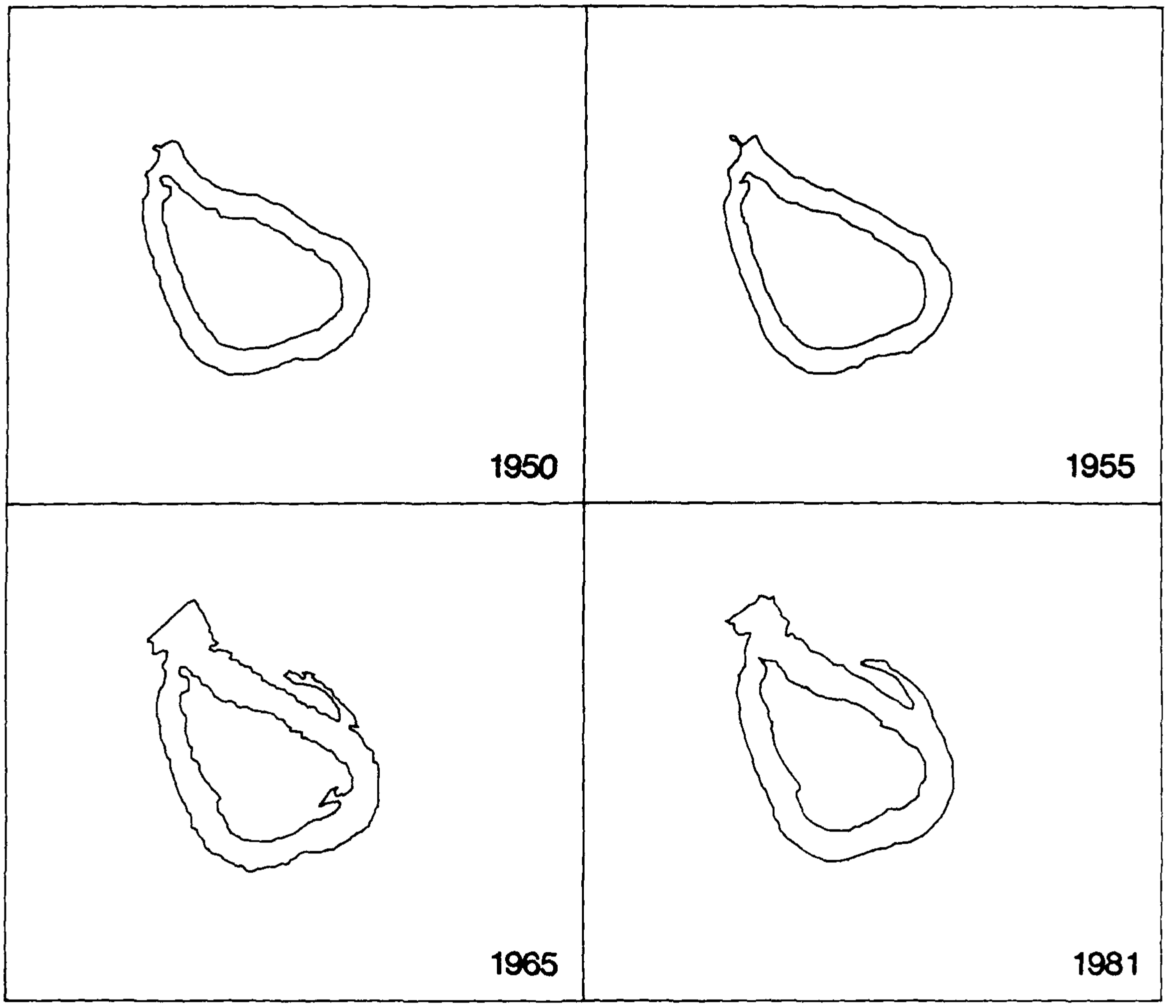


Figure B21. Site BW2, Bohanon's Cutoff, Black Warrior River, 9 miles northeast of Eutaw, AL. Site BW2 is a natural oxbow that was cut off between 1936 and 1950. Old Lock and Dam No. 8, located 6 miles downstream, was closed in 1903, providing a 6-ft navigation channel. The dam was raised in the late 1930s to provide a 9-ft navigation channel. Selden Lock and Dam, located 23 miles downstream, was closed and the navigation pool impounded in October 1957

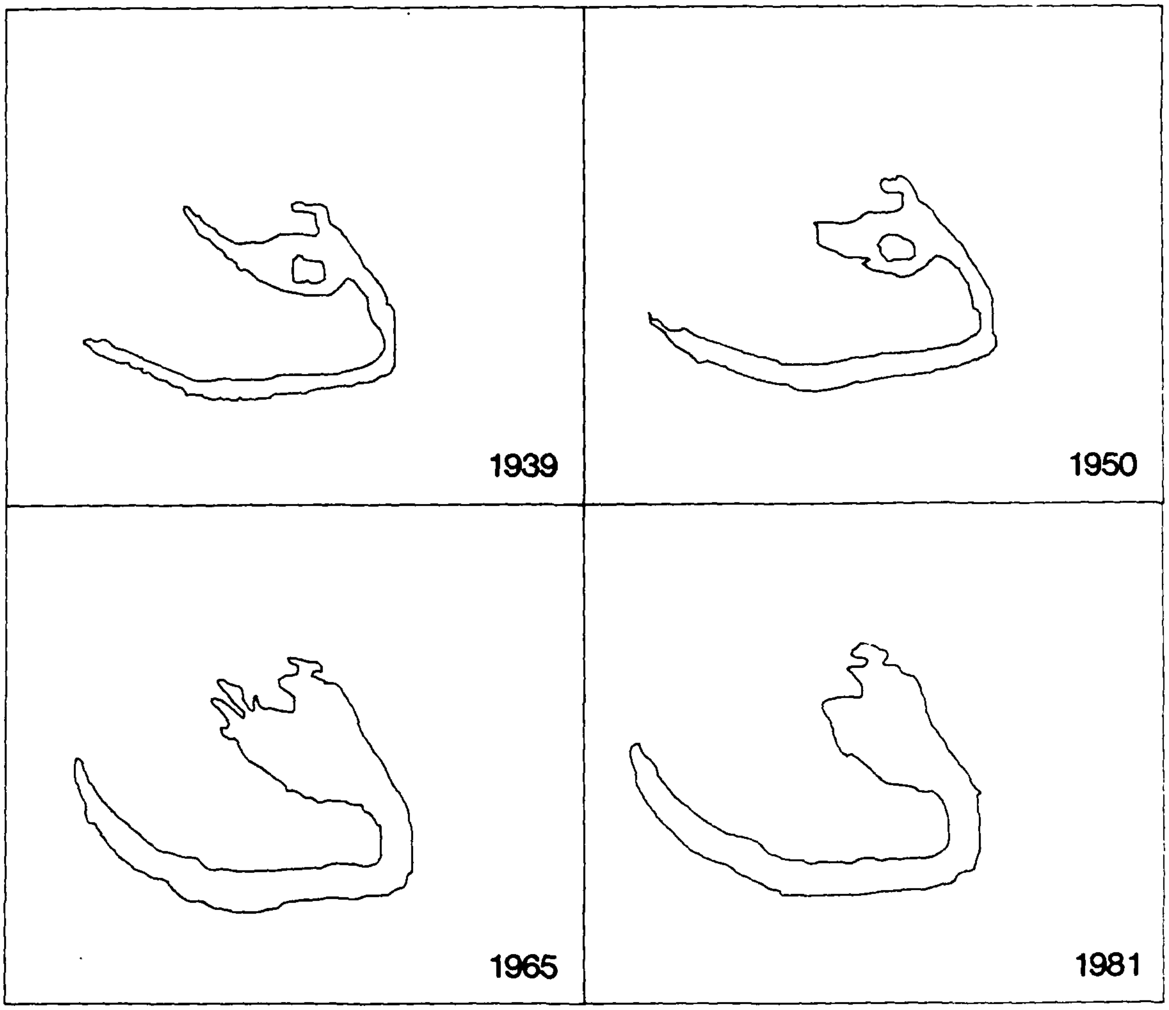


Figure B22. Site BW3, King's Cutoff, Black Warrior River, 5 miles south of Tuscaloosa, AL. Site BW3 is a natural oxbow that was cut off before 1938. Old Lock and Dam No. 18, located 13 miles downstream, was closed in 1903, providing a 6-ft navigation channel. The dam was raised in the late 1930s to provide a 9-ft navigation channel. Selden Lock and Dam, located 30 miles downstream, was closed and the navigation pool impounded in October 1957

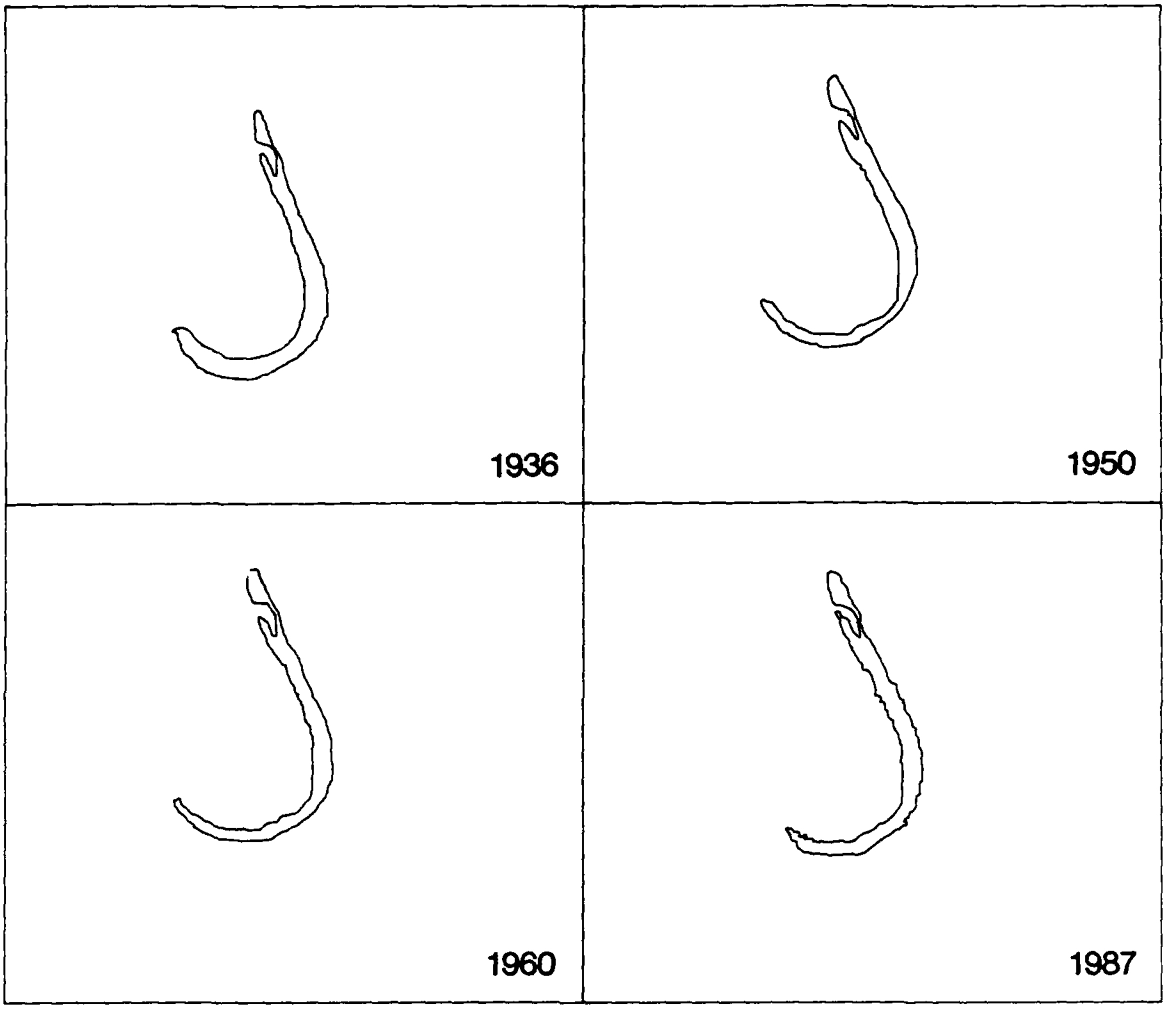


Figure B23. Site BW4, Keaton Lake, Black Warrior River, near Tuscaloosa, AL. Site BW4 is a natural oxbow that was cut off before 1938. Old Lock and Dam No. 9, located 3 miles downstream, was closed in 1903, providing a 6-ft navigation channel. The dam was raised in the late 1930s to provide a 9-ft navigation channel. Selden Lock and Dam, located 35 miles downstream, was closed and the navigation pool impounded in October 1957

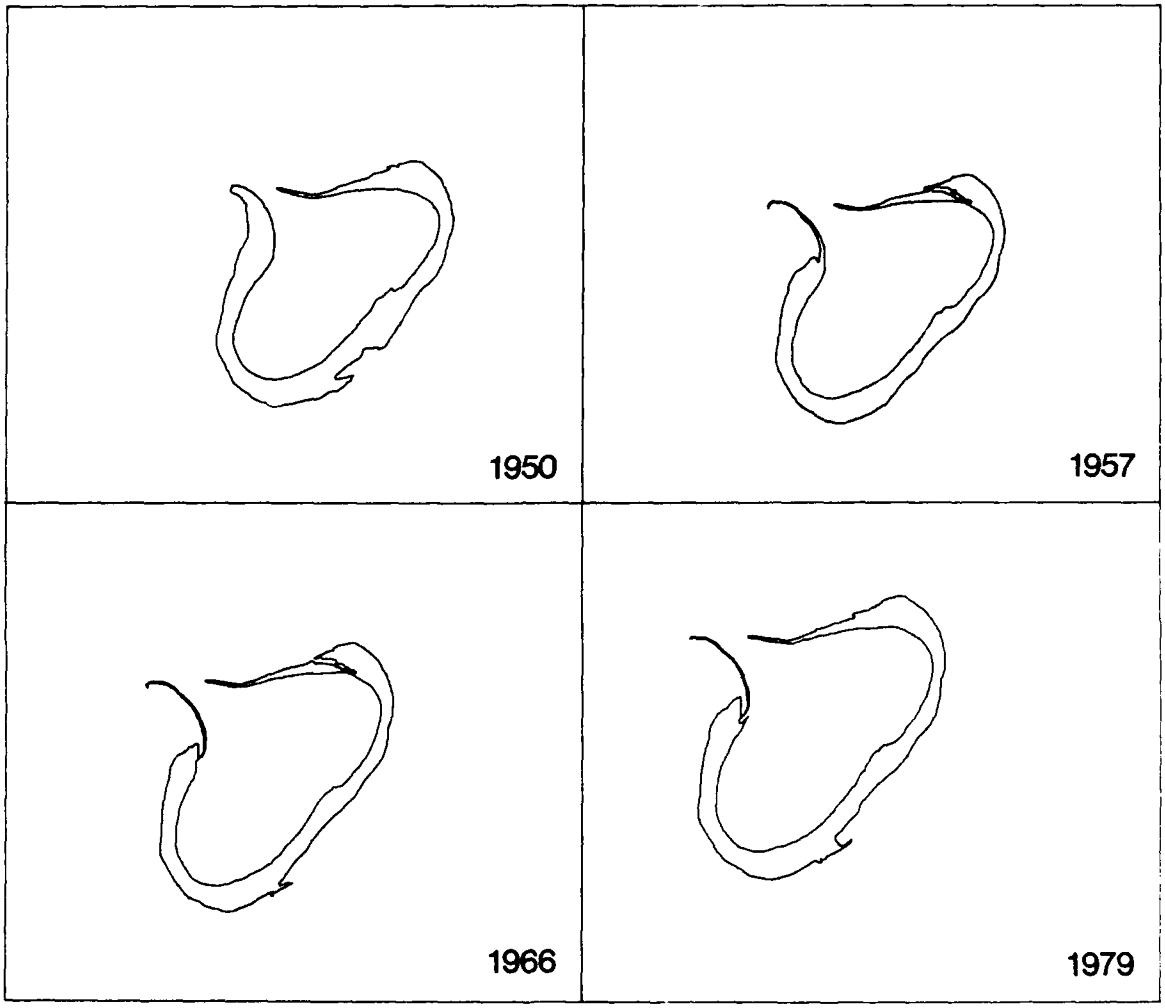


Figure B24. Site M1, Hardin, Mississippi River, about 10 miles north of Helena, AR. Site M1 is a man-made cutoff constructed in 1942

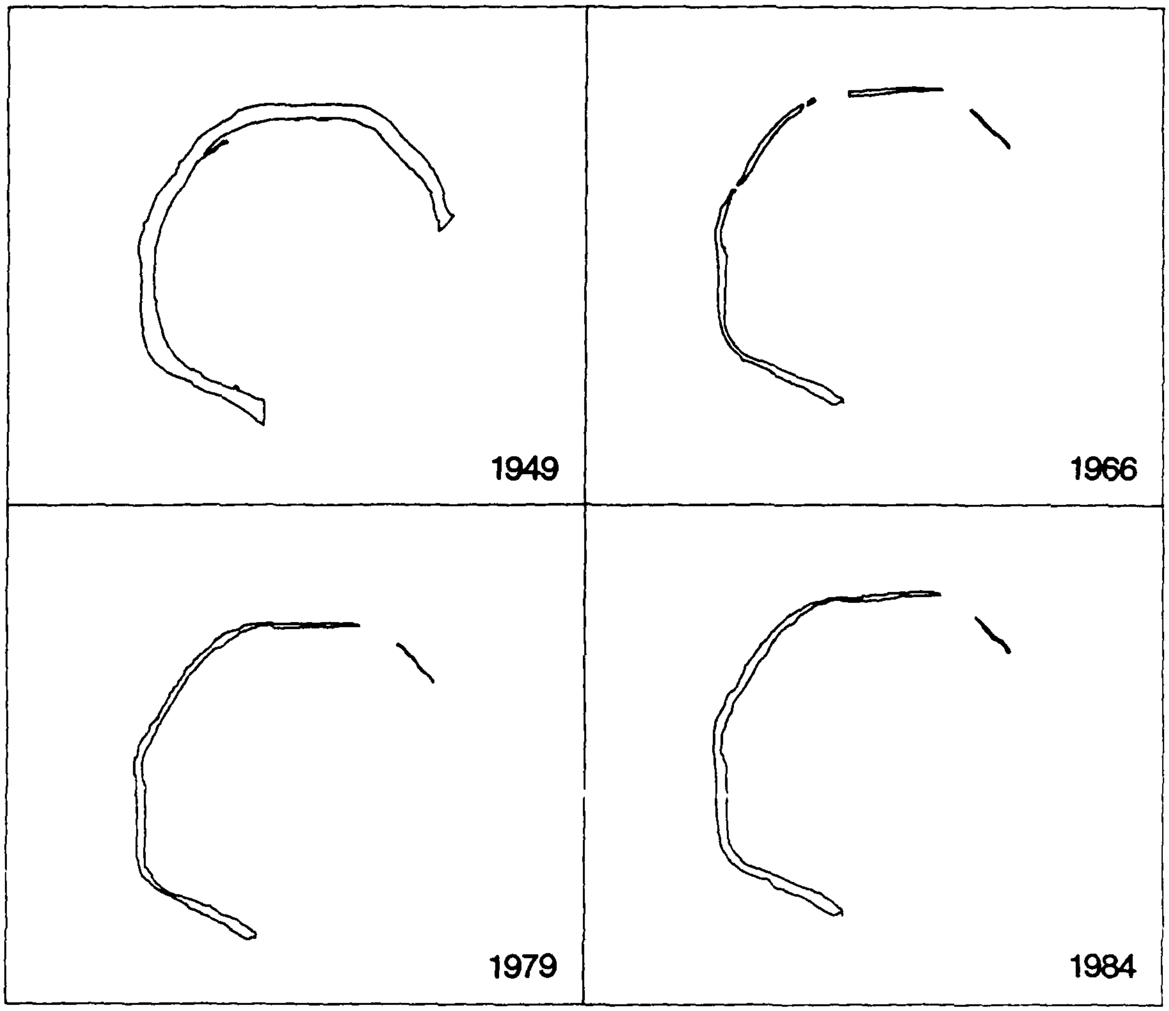


Figure B25. Site M2, Worthington, Mississippi River, about 17 miles south of Greenville, MS. Site M2 is a man-made cutoff constructed in 1933

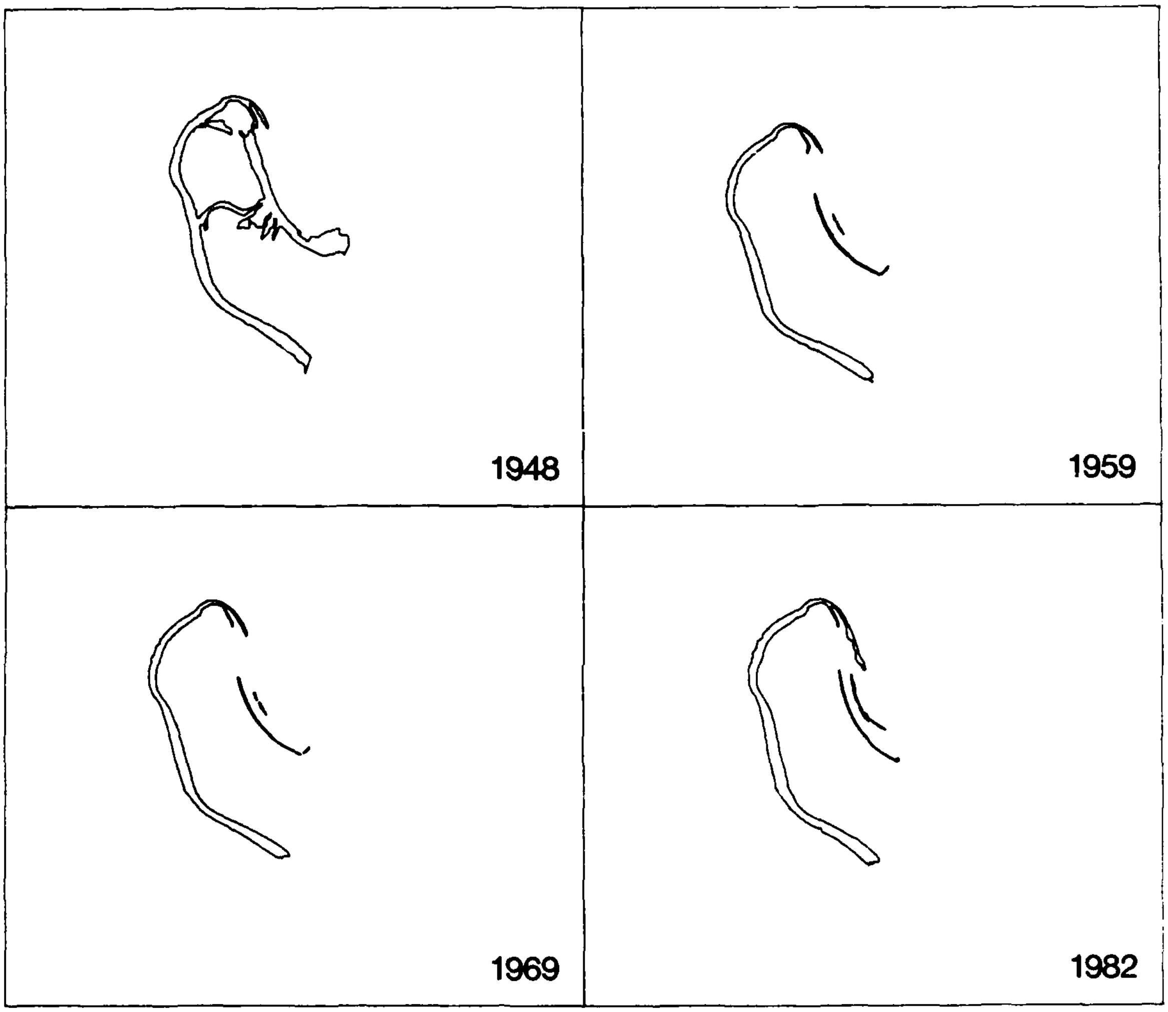


Figure B26. Site M3, Glassock, Mississippi River, about 15 miles south of Natchez, MS. Site M3 is a man-made cutoff constructed in 1933